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OF

The Institution of Engineers (India)

INCORPORATED 1920

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CONTENTS.

The Institution of Engineers (India)

Post Box 669, Calcutta.

Minutes of the Fifteenth Annual General Meeting held at 11 a.m. in the Office of the Institution, 6, Gokhale Road, Calcutta, on Wednesday, the 9th January, 1935.

PRESENT.

Mr. M. R. Atkins (in the Chair)
Sir James Pitkeathly
Dr. A. Jardine
Rai Bahadur B. P. Varma
Mr. A. C. Austin
,, S. N. Ghose
Mr. E. J. B. Greenwood
,, S. C. Griffin
,, N. B. Macbeth
,, Raja Ram
,, D. H. Remfry
Col. S. C. Temple
Mr. A. T. Weston

33 Corporate Members,

6 Students.

Mr. C. C. Seal (Secretary).

PROCEEDINGS.

Mr. M. R. Atkins took the Chair at 11 a.m.

The Secretary read the Notice convening the Meeting.

1. The Minutes of the Fourteenth Annual General Meeting having been circulated were taken as read and confirmed.

2. The Annual Report of the Council and the Audited Accounts for the year ended 31st August 1934 were handed to all members present.

   The Chairman dealt with the Report briefly and explained the various items in the Accounts.

   It was proposed by Mr. S. N. Ghose that the Report and the Accounts be adopted and passed.

   This was seconded by Lt.-Col. M. Stagg and was carried.

3. It was proposed by Mr. T. A. Curry that Messrs. Price, Waterhouse, Peat & Co., be re-appointed Auditors for the year 1934-35 at a remuneration of Rs. 350/- per annum.

This was seconded by Mr. E. J. B. Greenwood and was carried.

4. The Chairman reported that the Council had elected Rai Bahadur B. P. Varma as President of the Institution for the year 1934-35.

5. The Chairman reported that under Article 9 of the Constitution the following Members had been elected by the Local Centres to fill the vacancies on the Council:—

Mr. S. N. Ghose ,, A. Macdonald	Bengal Centre.
Dewan Bahadur A. V. Ramalinga Aiyar Dr. K. C. Chakko Mr. E. J. B. Greenwood Diwan Bahadur N. N. Ayyangar	South India Centre.
Mr. Raj Narain ,, Mohsin Ali Rai Bahadur Chuttan Lal	United Provinces Centre.

6. The Chairman reported that under Article 9 the following Chairmen of Local Centres are ex officio Vice-Presidents of the Institution:—

Mr. A. C. Austin ...	Bengal Centre.
,, Framroz D. Mehta ...	Bombay Centre.
,, R. H. Martin ...	South India Centre.
Khan Bahadur M. Abdul Aziz	United Provinces Centre.

7. The Chairman referred to the Secretary's note on the financial effect of the proposal for reduction of Subscriptions which had been circulated with the Agenda, and pointed out that in the circumstances explained therein it would not be prudent to reduce the Subscriptions until the amount borrowed from the Capital Reserve Fund had been made good. He suggested that the matter be left in the hands of the Council.

This was unanimously agreed to.

8. The Chairman announced that the British National Committee of the World Power Conference had invited this Institution to participate in the Chemical Engineering Congress to be held in London in the Autumn of 1935.

He asked any members who wished to attend the Congress, to communicate with the Secretary to enable the latter to send their names to the Chairman of the Congress.

9. The Chairman asked Rai Bahadur B. P. Varma the new President to take the Chair.

10. Rai Bahadur B. P. Varma took the Chair and delivered his Presidential Address.

The Institution of Engineers (India).

ANNUAL REPORT OF THE COUNCIL

For the Year ended 31st August, 1934.

MEMBERSHIP.

The changes in the Membership during the year are shown in the following table :—

	Honorary Members.	Hon. Life Members.	Life Members.	Members.	Life Assoc. Members.	Associate Members.	Companions.	Students.	Associates.	Subscribers.	TOTALS.
Membership on 31st August, 1933 ..	11	2	63	334	3	585	3	196	39	17	1,253
Additions up to 31st August, 1934 :—											
Elected	..	..	..	11	.	39	..	53	2	1	106
Transferred ..	..	.	4	10	.	7	..	..	..	..	21
Total additions ..	..	..	4	21	..	46	..	53	2	1	127
Deductions up to 31st August, 1934—											
Transferred ..	..	..		4	..	10	..	7	..	..	21
Deceased ..	..	..	..	2	1	3	..	..	..	..	6
Resigned ..	..	.	..	10	..	15		17	1	..	43
Struck off ..	..	..	..	15	..	16	..	34	..	..	65
Total deductions ..	..	..	..	31	1	44	..	58	1	..	135
Membership on 31st August, 1934 ..	11	2	67	324	2	587	3	191	40	18	1,245

106 members joined the Institution, 43 members resigned and 6 members died during the year. The names of 41 members were removed from the Membership Register for non-payment of subscription and 24 students ceased to be members of the Institution

as they reached the age limit. This resulted in a net decrease of 8 members against 22 in the previous year.

The following members retired from the Council during the year :—

Mr. P. N. Banerjee.
Col. F. C. Temple.
Mr. F. E. Bharucha.
" J. P. Bradshaw.
Dr. G. W. Burley.
Dewan Bahadur K. R. Godbole.
Mr. S. K. Gurtu.
Col. Sir George Willis.
Rai Bahadur M. C. Bijawat.
Rai Bahadur C. V. Krishnaswamy Chetty.

The following members were re-elected :—

Mr. P. N. Banerjee.
Col. F. C. Temple.
Mr. F. E. Bharucha.
Dr. G. W. Burley.
Dewan Bahadur K. R. Godbole.
Mr. S. K. Gurtu.
Col. Sir George Willis.
Rai Bahadur M. C. Bijawat.

The following members were newly elected :—

Rao Bahadur G. Nagaratnam Ayyar.
Mr. N. V. Modak.

LOCAL CENTRES.

During the year Local Centres made good progress. Papers of considerable merit were read and discussed. Interesting lectures were delivered and many places of engineering interest were visited by the members.

The satisfactory progress maintained by the Local Centres is largely due to the keen interest taken by the Honorary Secretaries. The Council takes this opportunity of conveying to them its grateful thanks.

BRITISH STANDARD SPECIFICATIONS.

The Institution continued to act as the Indian Committee of the British Standards Institution and, as a result of the increasing activities of that body, a large number of specifications were dealt with, covering a considerably wider field than was formerly the case.

The Council found it necessary to consider a modification in the procedure adopted for dealing with draft specifications. Hitherto they had been referred to members of the Specifications Committee which was responsible for deciding what steps were necessary in order to ascertain the views of representative persons

and firms in India, and for collating the opinions received, or, if necessary, appointing a Sub-Committee of experts to deal with the reference. As members of the Specifications Committee were in various Local Centres of the Institution, meetings could not be held. The business of the Committee was therefore necessarily conducted by correspondence. This led to some difficulty when dealing with urgent references, and in general the system proved somewhat cumbersome and difficult to follow as the number of specifications to be dealt with increased and the scope widened. It was therefore decided to appoint an Adviser on Specifications who would decide the procedure to be adopted in each individual case in order to obtain representative opinion, thus relieving members of the Specifications Committee of purely routine duties. It was also decided to obtain the services of members of the Institution and others who would act as Chairmen of Sections to deal with references appertaining to their particular professional branch. The new system is at present in the transition stage.

During the year under review a large number of draft specifications were considered and commented upon, special consideration being given to their suitability to Indian conditions and requirements. The Council takes this opportunity of thanking those members of the Institution, and others, who have contributed their views and suggestions. The Council would be glad if members who are interested in standard specifications, whether from the manufacturer's or user's standpoint, and who would be willing to assist the Institution i. this important work, would signify their readiness to help, stating the particular branch of Engineering and type of specification upon which they are best qualified to offer criticism.

INTERNATIONAL ELECTRO-TECHNICAL COMMISSION AND THE WORLD POWER CONFERENCE.

The Council continued to act as the National Committee of the International Electro-technical Commission and the World Power Conference.

JOURNAL.

Volume XIII of the Journal containing Papers accepted by the Institution and discussions thereon was issued in July, 1934.

BULLETINS.

3 Bulletins (Nos. 41, 42 and 43) were issued during the year. They contained much useful information, such as additions to

the Membership list, particulars of new and revised Standard Specifications and matters of general interest.

ANNUAL SESSION.

The 14th Annual Session was held in New Delhi in January 1934. The Annual General Meeting was presided over by Sir Guthrie Russell, and H. E. the Viceroy of India graced the occasion with his presence at the Annual Dinner. Members attending the Session made a tour of the Imperial City and visited the following places:—(a) The Kilokri Sewage Pumping Station and farm, (b) Bijai Mandal and other Archaeological buildings near Qutab and (c) New Delhi Power Station and unfiltered Water Pumping Station. Also there was a Papers Meeting in which the following papers were discussed:—

(a) "TEMPERATURE STRESSES IN REINFORCED BRICKWORK AND THE FAILURE OF REINFORCED BRICKWORK ROOFS" by Prof. Raja Ram and Mr. Anand Saroop.

(b) "THE POSSIBILITY OF FLOOD REGULATION AND CONSERVATION IN THE HIMALAYAS FOR IRRIGATION OR POWER" by Mr. J. W. Meares.

EXAMINATIONS.

The Preliminary and Associate Membership Examinations were held in October, 1933. There were 19 candidates for Part A, and 17 for Part B of the Associate Membership Examination. Of these 7 passed in Part A, and 6 in Part B. There was only one candidate for the Preliminary Examination and he was unsuccessful.

VICEROY'S EARTHQUAKE RELIEF FUND.

With a view to contributing Rs. 1,000/- to H. E. the Viceroy's Earthquake Relief Fund, a fund was started by the Institution. The members were invited to contribute Re. 1/- each to this fund. The total collection amounted to Rs. 730/9/- and this amount was duly paid into H. E. the Viceroy's Earthquake Relief Fund.

H. E. THE VICEROY'S PRIZE.

This prize, value Rs. 500/-, was awarded to Mr. A. R. Beattie, Member, for his paper—"The B. T. U. IN AN INDIAN PAPER MILL."

ROYAL CHARTER.

The necessary petition was drafted and signed for the purpose of submission to His Majesty's Government.

HONOURS.

Honours were conferred on the following members of the Institution.

Knighthood	...	Sir Maurice M. Brayshay.
Diwan Bahadur	...	Diwan Bahadur N. N. Ayyangar.
O. B. E.	...	Mr. H. P. Bhaumik.

ACCOUNTS.

The audited accounts for the year is appended.

The Institution of Engineers (India).

BALANCE SHEET AS AT 31ST AUGUST, 1934.

LIABILITIES & SUNDRY CREDIT BALANCES.

CAPITAL—			
Permanent Reserve Account—			
As per last account ...		77,442 6 3	
Add:—Entrance Fees	1,880 0 0		
Composition Fees	214 0 0		
Transfer Fees ...	80 0 0	2,174 0 0	
		79,616 6 3	
Donations		3,678 7 7	
Building Fund—			
As per last Account ...	79,862 4 6		
Receipts ..	260 8 0	80,122 12 6	1,63,417 10 4
Subscriptions in advance ...			1,186 2 4
Suspense			168 2 0
LIABILITIES—			
For Expenses		575 0 6	
Sundry Creditors		681 4 0	1,256 4 6
B. E. S. A. Allowance Fund			1,719 11 6
National Electro-Technical Committee for India			83 4 2
Library Deposit			25 0 0
Viceroy's Prize			500 0 0
Imperial Bank of India			
(Secured on Investments)			9,694 11 6
Purchase of Books			946 5 1
Examination Fees in Advance			2,322 0 0
Carried over Rs. ...			1,81,319 3 5

ASSETS & SUNDRY DEBIT BALANCES.

Building—			
As per last Account		...79,466 0 6	
Less:—Depreciation as per last Account	3,973 4 8		
Less:—Depreciation during the year	1986 10 4	5,959 15 0	73,506 1 6
Furniture and Fittings—			
As per last Account		... 11,336 8 3	
Addition during the year		... 1,114 4 6	
		12,450 12 9	
Less:—Depreciation		... 790 7 3	11,660 5 6
Outstanding Subscriptions (of which Rs. 3,900 is considered doubtful)			8,411 15 2
Sundry Debtors—Considered Good			1,745 14 6
Deposit U. P. Centre			50 8 0
Stock—Stationery			46 0 0
Investments—			
5% Loan of 1939—44 for Rs. 67,800		63,348 2 0	
4½% „ „ 1955—60 „ „ 14,000		13,228 5 0	
4% „ „ 1960—70 „ „ 5,000		5,000 0 0	81,576 7 0
Rs 86,800			
Note:—Market Value as at 31st August 1934 Rs. 94,798 4 0			
Alliance Bank of Simla Ltd (In Liqn.)—			
(Recovery Doubtful).			
On Permanent Reserve Account		5,351 15 0	
„ Donation Account ...		11,771 1 1	
„ Suspense Account ...		5,298 1 4	
„ Bengal Centre Account ...		35 13 10	
		22,456 15 3	
Less:—Recovered		17,516 2 8	4,940 12 7
Carried over Rs.			1,81,938 0 3

				Rs. As. P.
Brought forward Rs.				1,81,319 3 5
Income and Expenditure Account—				
Excess of Income over Expenditure during the year ..			17,444 2 1	
Less:—Dr. Balance as per last Account	15,680 14 3			
Add:—Adjustments referring to former period	70 0 0			
	15,750 14 3			
Less:—Adjustments referring to former period	42 7 0	15,708 7 3		1,735 10 10
Total Rs.				1,83,054 14 3

			Rs. A. P.
Brought forward Rs.			1,81,938 0 3
Charges Recoverable—Considered Good—			45 1 10
Cash—			
In hand		74 14 2	
At Local Centres		996 14 0	1,071 12 2
Total Rs.			1,83,054 14 3

We have audited the above Balance Sheet with the Books of the Institution of Engineers (India), in which are incorporated the certified Returns from the Local Centres and have obtained all the information and explanations we have required. In our opinion such Balance Sheet is drawn up in conformity with the Law and exhibits a true and correct view of the Institution's affairs according to the best of our information and the explanations received by us and as shown by the Books of the Institution.

(Sd.) PRICE, WATERHOUSE, PEAT & CO.,

Chartered Accountants }
Registered Accountants. } Auditors.

CALCUTTA,
18th December, 1934.

The Institution of Engineers (India.)

STATEMENT OF INCOME & EXPENDITURE ACCOUNT FOR THE YEAR ENDING 31ST AUGUST 1934.

EXPENDITURE.

	Rs.	As.	P.			
To Salaries and Wages ...	14,656	12	9			
" Postages	1,373	8	6			
" Telegrams	53	5	6			
" Printing	577	15	0			
" Stationery	1,353	14	0			
" Conveyances	225	2	6			
" Rent and Taxes	4,813	4	0			
" Lighting and Fans ...	304	5	6			
" Journal	1,096	2	8			
" Bulletins	678	4	3			
" Issue of Papers	869	14	3			
" Annual Meeting	1,047	14	0			
" Diplomas	77	12	9			
" Audit Fees	350	0	0			
" Charges General	1,411	1	4			
" Telephone	184	2	11			
" Examination	169	8	9			
" Subsidy to Local Centres ...	37	2	6			
" Bad Debts	4,145	5	2			
" Depreciation (Building) ...	1,986	10	4			
" Depreciation (Furniture) ...	790	7	3			
" Gratuity	150	0	0			
" Law Charges	4	0	0			
" Advertisement	120	11	0			
" Repairs to Building ...	140	8	0			
				36,617	12	11
" Balance being excess of Income over Expenditure transferred to Balance Sheet ...				17,444	0	1
				54,061	15	0

INCOME.

	Rs.	As.	P.
By Subscriptions	50,146	0	0
" Interest	3,549	7	7
" Sale of Standard Specifications.	256	8	5
" Sale of Publications ...	109	15	0
Total Rs.	54,061	15	0

PRESIDENTIAL ADDRESS

BY

Rai Bahadur B. P. VARMA.

PRESIDENT 1934-35.

Gentlemen,

I am fully conscious of the honour which the members of the Institution of Engineers (India) have done me by electing me as their President for the coming year. Not having been directly in touch with actual engineering for the last five years except on the recruiting side, the membership of this Institution has been my only link with the general profession. I can, therefore, hardly claim to deserve such an honour, which I regard as the greatest that can be conferred by one's brother engineers in this or any other country. Gentlemen, I thank you most sincerely for this honour.

I joined the Punjab Irrigation in 1898 when the practical side of canal hydraulics was in its infancy. While surveying or going about my works in the jungles of the Punjab, I could have hardly dreamt of the rapid and substantial advances which the science of engineering, in its various branches including Irrigation, has actually made during this interval of thirty six years. I often used to come across difficulties and had recourse to crude devices to get over them. Being situated in remote corners of the Province any help by way of advice or consultartion with senior engineers on such occasions was out of the question. It was on such occasions that the idea of an associartion where engineers could meet for an exchange of views or for rendering advice to the younger members of the profession, used to come to my mind. However, situated as I was, the idea only grew with my helplessness till 1905 when through the help of some senior members it materialised in the shape of "The Engineers' Association, Punjab." The Punjab Engineering Congress followed it six years later in 1911, and while the former served a very useful purpose as a pioneer, the Congress has during the last twenty-four years of its life done solid work for the good of the Province. The inauguration of this Institution in 1921 was the fulfilment, in the true sense, of my early hopes and desires. The Institution, gentlemen, though a comparatively young body, has already

achieved a great deal, and I have no doubt that greater achievements await it in the future.

The earlier history of the engineering profession is enshrouded in mystery and dates back to the hoary past or the advent of the human race on the surface of this planet. The progress of human civilisation synchronises with the advances made in the science of engineering. The relics of bygone ages proclaim this fact and it is difficult to say whether even better performances by the engineers of the past have not been lost to us through the destructive agency of natural forces or human invaders, just as some of "The Seven Wonders of the Old World" seem to have disappeared. The relics of a very old civilisation, those at Mohenjodaro in Sind, were unearthed not very long ago. They are said to be the oldest so far discovered in India; and those who have examined the ruins carefully, declare that it must have been an up to date and magnificent town of its day. Whatever the town may have been like, one thing is certain, gentlemen, viz. that its builders had provided it with an efficient drainage system, both surface and underground. The grandeur of its houses, walls, baths and gates can be realised only insufficiently at present from their size, decorations and other small remnants found in the ruins, but the system of drains has not been so badly damaged and can be seen and appreciated. Those who have studied it closely and carefully tell me that it is as good as, if not better than, that of any newly laid out modern town. Gentlemen, I consider this as high praise for the ancient town planners and builders of Mohenjodaro. Being the followers of that illustrious crowd, we should feel proud to belong to their profession and, at the same time, be able to boast of having this Institution to look after and safeguard our intersets, which perhaps the engineers of Mohenjodaro did not have. Gentlemen, we ought to be doubly proud that we have to day gathered under the roof of our "mother institution" in this country, embracing as she does all those who practise engineering or could call themselves members of that profession.

The work of a large number of engineers lies in remote and distant corners of this large country, and they have to carry it out not only under varying conditions of climate and temperature but also under certain local difficulties peculiar to the place. If I may say so, gentlemen, the ravages caused by the great Earthquake of January 1934 in certain parts of your own and the adjoining province of Bihar and Orissa, will occur to you as furnishing examples of peculiar and local difficulties. Engineers, and may-be several of our members, have taken and are still taking

a prominent part in repairing the damage done; but I would be departing from my own subject if I proceed further to enlighten you on some of their difficulties met with in the discharge of their duties. I, however, trust that my friend Colonel Temple, the Relief Engineer and Supply Officer of the Bihar and Orissa Government, who has had first-hand knowledge of the conditions of the tract, would tell us something of his experiences on some suitable occasion. Whenever he does so, I am sure they will prove both very interesting and instructive.

To return to my subject, gentlemen, when similar problems are met and faced at two different places, requiring different treatment and handling, a free and frank discussion of their merits can not but whet our wits and infuse zeal and enthusiasm into our efforts for further investigations. By providing means for discussing and exchanging views on such problems, we not only enhance our knowledge but call upon the capacity and talents of those engaged in such discussions to make further efforts to discover the truth about the hidden laws of nature and to understand them. When the disease has been correctly diagnosed, the problem of its cure becomes easy. Whatever branch of engineering we may turn our attention to, a closer study of these laws becomes more and more desirable, because as the science progresses, its conflict with nature becomes more and more acute, and if a mistake is made, nature is sure to find us out and punish us. For this reason, the engineers of not very long ago (say 40 years back) were rightly advised to proceed cautiously while trying to harness the forces of nature for the service of man. The engineers of the present day can go forward more rapidly and confidently if literature dealing with the past experience and knowledge of those who worked in the same or similar fields before them, is available for their use. This knowledge and experience is not only of great help to them but will save lot of time, trouble and money of all concerned.

In the old days engineers used to come and go and carry their experience and knowledge of Indian problems with them to countries and places where it was of little use. Usually, the major portion of it was lost for ever, though a small fraction was perhaps preserved in books or pamphlets published in countries other than India. This record, therefore, was not readily accessible or of much value to engineers working in this country. The establishment of this Institution has provided a suitable repository and a sure means of disseminating such knowledge. The Institution has not failed to recognise this as one of its foremost functions, but, as far as I know, not on any organised lines. The

only good and useful model for this sort of work that I know of is the Central Board of Irrigation and its Information Bureau. It, however, concerns itself only with Irrigation problems, and it will be readily admitted that one board, however well-equipped it may be cannot meet the general requirements of every branch of the engineering profession. Separate boards are required and will have to be set up for Sanitary, Mechanical, Electrical and other branches of the profession to overcome this difficulty.

In other countries, like England and America, different branches of engineering are represented by associations and societies of their own. Unlike them, our Institution comprises all the branches of the profession over the whole of India. This, gentlemen, is a gigantic undertaking and, though quite worthy of this robust and young society, it needs a well thought out plan for the development of its several branches side by side. I am quite hopeful that with the assistance of our members spread all over the country we shall in a short time be able to collect and disseminate a vast store of knowledge and information about engineering and its present day practices suited to the peculiar conditions and needs of this country.

I also think, and it will be readily admitted, that, unlike other countries, the conditions under which engineering works are undertaken, designed or built change from province to province in this country, and require particular treatment and handling; and for this reason also the collection of a variety of experience has become a necessity for the profession.

For all these reasons I wish and would recommend that a bureau be formed and administered by this Institution, dealing separately with all its branches. It may not be possible to make a start on a comprehensive scale dealing with all the branches, but we may begin with as many as can be tackled at present, adding on others and sub dividing all or any of them as necessity arises or experience demands. I would suggest the names of the following branches of engineering with a central office at Calcutta and branches at suitable local centres for a beginning:—

1. Civil Engineering.
2. Electrical Engineering.
3. Structural and Architectural Engineering.
4. Sanitary Engineering.
5. Mechanical Engineering.
6. Metallurgical Engineering.
7. Industrial including Technological and Chemical Engineering.

Engineers, as a rule, are generous in imparting their own experience and knowledge to others, and I therefore feel quite confident that our own members, and other eminent engineers not as yet within our fold, would help our Institution in this under- [illegible]

[illegible] and colleges have increased—in fact, each Province can claim at least one to itself, if not more—and consequently the number of engineering students and graduates has been increasing from year to year, so much so that it has become impossible to find employment for them in the services under the Government of the country. Undoubtedly, trades and industries have also been developing side by side and ought to have absorbed a large number of young engineers for work and training, but unfortunately, on account of financial stringency and trade depression, this has not been possible. The engineering schools and colleges of India should therefore try to keep abreast of the present day requirements of the trades and industries of the country. Their technical courses should be moulded as far as possible in accordance with those requirements and their practical training should also follow suit. More importance should be attached to specialisation, because without that it would be difficult for students to find employment in trade or industry. In short, the students should be prepared as much for employment in trades and industries as under Government, and the training imparted should be of a nature to befit them practically for some special class of work.

In Government service there is no doubt the advantage that the candidate is given some training in the special class of work which he will be required to do during his service; whereas trades and industries require trained hands. It is also somewhat unfortunate that the right kind of training in several branches of the profession is difficult to obtain in India. In cases where it cannot be obtained in India, the student should be advised by his college authorities to visit some foreign country where it may be

obtainable. When such advice is given, I trust that due regard will be paid to the conditions prevailing in this country in regard to the particular branch of the profession or industry in which the student desires to be trained.

[illegible] he student of engineering has necessarily to [illegible] r that of others, and it is the duty of our [illegible] to widen it by bringing their students face to [illegible] y increasing their powers of observation, and [illegible] aracter by teaching self reliance, honest work [illegible] ty.

[illegible] that the engineering colleges and schools can [illegible] s in this respect, but I would like them further [illegible] y step forward nowadays means more acute [illegible] re. The signs of the times show that import- [illegible] ached to specialisation after a proper theoretical course and practical training. A smattering of education in all or some of the branches of the profession will not prove of much help to the students. In fact, it would have been preferable if some of the engineering colleges had specialised in only one or two branches of the science of engineering and not sacrificed efficiency to comprehensiveness. Practical training is as much necessary as theoretical, and the colleges will have to combine with their theory and practice the development of character in their students, so necessary for an engineer in his after life. As the colleges belong to different provinces, their outlook is naturally, more or less, provincial, and thus some of them may find it difficult to recast their courses of education and practical training on the lines suggested. Hence, I think that this work should better be done under the advice and guidance of this Institution and in conformity with the peculiar requirements, if any, of the provinces concerned. The Institution represents the profession in India and should be able to accomplish this task untrammelled by any considerations other than those of purely professional interests and the necessity of improving and accelerating the education of engineers in this country.

The fact that the schools and colleges belong to different provinces ought not to prove a bar or obstacle in the way of this work, as it is not proposed to do anything against provincial interests. The teaching institutions will all remain provincial assets as at present, but the outlook of their education and training will be improved in such a way that it will not be confined to the provinces but will cover the interests of the whole country and of the profession in general. In other words, the colleges

should be able to supply suitable hands properly educated and [illegible] ... done by the [illegible] and [illegible] exercising the necessary checks in this direction, [illegible] advantage of the [illegible] of engineering [illegible] country.

Those of our young men who have recently joined the profession should not lose heart because due to financial stringency the future outlook is not quite bright and the conditions as regards employment in Government Service, trades or industries more difficult than before. I am sure these conditions are not going to stay with us for ever. Our country has enormous resources, such as large culturable areas, vast geological and mineral deposits, and sure chances of obtaining cheap power. These resources, if properly utilised and developed, should have a marked and healthy effect on the economic aspect of the country and its inhabitants. In any profession progress requires patient, persistent and repeated efforts, and every step forward has to be thought out, as proceeding in a hurry would be courting failure. Bearing this in mind, I think the work before our engineers is not only huge but such as promises a glorious field for their activities, if they only apply themselves to it sincerely, with courage and an indomitable will. Tell me of any other profession with such magnificent and attractive prospects before it.

For the class of development work mentioned above engineers with imagination, self-confidence and character will be required, but they alone will not suffice, and nothing will be done till they join hands with a body of industrialists well qualified and trained in their own lines. This combination of capital, intelligence and

labour should result in an addition to the productive capacity of [illegible] and its output of manufactured articles, and thus [illegible] an era of economic prosperity. This plan has been [illegible] has proved successful in other countries with much [illegible]ources as compared to our own, and I do not see why [illegible]sults should not follow our efforts in this country.

[illegible] times are unpropitious and hard, I would ask the [illegible]bers of the profession not to be apathetic or in- [illegible]or have undesirable jealousies with other members of [illegible]ion, as that is likely to retard progress. As members [illegible]tution we should be ever ready, within possible limits, [illegible]elping hand to our professional brothers, whoever and [illegible]hey may be.

THE FIFTEENTH ANNUAL DINNER.

The Fifteenth Annual Dinner of the Institution of Engineers (India) was held at Peliti's Restaurant, Calcutta, on 10th January, 1935.

Rai Bahadur B. P. Varma, President of the Institution, presided. His Excellency the Governor of Bengal honoured the Institution with his presence as the Chief Guest. The other guests were the Hon'ble Sir Brojendra Lall Mitter, the Hon'ble Sir John Woodhead, the Hon'ble Nawab K. G M. Faruqui, Dr. L. L. Fermor, Sir Thomas Ainscough, Mr. C. W. Gurner, Lt.-Col H. N. G. Geary, Mr. N. V. H. Symons and Mr. N. N. Sen Gupta.

His Excellency the Governor of Bengal proposed the Toast of "THE KING EMPEROR."

The President in proposing the Toast of "HIS EXCELLENCY THE GOVERNOR OF BENGAL" said:—
Your Excellency,

On behalf of the members of the Institution of Engineers (India) it is my most pleasant duty to extend to Your Excellency a hearty welcome and to offer our grateful thanks for your presence here to night. We all know, Sir, that till yesterday you were fully occupied with the visit of Their Excellencies the Viceroy and the Countess of Willingdon to your capital, and the fact that you accepted our invitation shows what a keen interest you take in matters pertaining to our profession.

I am not quite a stranger to Your Excellency, having had the pleasure and privilege of meeting you at Delhi nearly two years ago, soon after you had assumed charge of this, the largest and most populous province of India. The Presidency of Bengal, over which Your Excellency holds sway, can easily boast of as many engineering achievements as her sister provinces, while the city of Calcutta, where we are assembled to night, has been very fittingly called "a monument of great engineering achievements, the home of industries, and the centre from which has radiated so much that is concerned with the development of India".

Nor is Your Excellency unfamiliar with one of the principal sources from which so much inspiration in the engineering sphere is derived. If there is any particular area in the British Isles to which we, professional engineers in India, may fittingly look as a spiritual home, it is perhaps to that small stretch of country which lies between the Tweed and the twilight of the highland mists. In whatever corner of the Empire one may penetrate, men from lowland, hill and town are to be found wrestling with the intractable forces of nature and imparting their knowledge freely, not according to the dead letter of the book, but spiced with a sage philosophy of life, and a humour never more conspicuous than in its alleged absence. I venture to think, Sir, that we in India have not been slow to profit by such instruction and can, by now, show many independent works worthy of our tutors.

I will not presume to compare the technical difficulties we have to overcome with the far greater administrative problems with which Your Excellency is faced; yet I am bold to suggest that those qualities of head and heart which you too have brought from that northern land and which we have watched you exercise so ably, provide an inspiring example, albeit in a higher sphere, of what we in our small way try to bring to our various tasks. Those tasks often keep us fully occupied. One of the largest rivers in this, or any other country cuts across your Province. Its behaviour is erratic, its strength prodigious. We have, it is true, spanned its waters to the great benefit of internal communications within the area, yet the river is for ever attempting to elude our grasp and unremitting care and watchfulness is the price we must pay for our victory.

Your Excellency's widespread sympathy with all that pertains to the development of the Province and the town of Calcutta is well known, these times of financial stringency notwithstanding. The interests of the engineering profession in all its branches are represented in this city, and I am sorry to say that they have suffered equally with the rest of India during the last five years or more. All the same, Sir, I assure you that the engineering fraternity is not downhearted but is confidently awaiting the return of more prosperous times. An engineer's duty has always been to serve his fellow-beings by controlling the natural forces around him in the interests of civilization. If an engineer feels a pride in rendering such service, I trust it will be pardoned. We have suffered in the immediate past but our spirits are high and the return of better times will, I hope, present us with renewed

opportunities of continuing our efforts. Hafiz of Shiraz, the famous poet of Persia, once said about the Soofies of his time:

هرگز نمیرد آنکه دلش زنده شد بعشق

ثبت است بر جریدهٔ عالم دوام ما

"That man never dies whose heart has been fired with the passion to serve his fellows, and so Our eternal existence is enrolled on the scroll of the universe."

These are brave words, and I think they are true of the best engineers of to-day as they were of the Soofies of old.

Gentlemen, I will not detain you longer, as there are other speakers also, whom you would wish to hear to-night. I now ask you to rise and drink to the health of His Excellency the Right Hon'ble Sir John Anderson, Governor of Bengal.

His Excellency the Governor of Bengal, in reply, said:--

MR. VARMA, GENTLEMEN,

Although it is less than a year since I last had the privilege and pleasure of dining with you as your guest at your Annual Dinner it is peculiarly true to say that much water has flowed under the bridges in those ten and a half months. In fact, those of you who have had responsibilities in connection with bridges--I am thinking at the moment more particularly of the Hardinge Bridge, but it is only one of many- will probably say that a great deal too much water has flowed and I can well imagine your feelings as the never-ceasing flood bore down upon you and threatened destruction to your handiwork which, great as it is, is puny compared to the Titanic forces which Nature is fond of loosing occasionally to prevent us mortals from having too good a conceit of ourselves.

I can also well imagine that, in moments of depression, possibly bordering on despair, at seeing vast volumes of surging water advancing as relentlessly as Time or Fate, you may have thought of an envied Noah who, when his constructional work was done could forget about it and could spend his time doing a pleasure cruise in the most complete travelling menagerie of which history holds any record. I have no doubt, however, that Noah had his problems and worries and that Zoology, catering problems and marine engineering to say nothing of a wife and several children kept him busy and anxious, for, as I get older, I tend to think that one of the truest things that has ever been said is "Man is born unto trouble as the sparks fly upward."

To night, however, you banish trouble and dull care and with easy consciences—I feel sure I am correct—forget about the toils and travails of the past year and comfort yourselves by good fellowship and good cheer.

The spirit of your dinner seems to have infused itself into me last year to such an extent that flinging to the winds that caution which is supposed to be characteristic of people who come from my part of the world I really let myself go. I don't habituallly use slang expressions but after re reading my speech I confess it occurred to my mind that an up to-date American might have described me as having "dribbled a bibful."

I said, and I meant what I said, the most resounding and magnificent things about Engineers and I said so many of them that there is almost nothing left for me to say without repeating myself.

Apart from the fact that it would be an insult to your memories to repeat myself, I object to doing so on principle. I am sure you will agree and that you would equally agree if you belonged to the sister profession of medicine that post prandial repetition in any form is, if possible, to be avoided.

Well, gentlemen, as you will see I have assumed that you do not want a long and serious speech on a festive occasion like this and I really intend to be quite brief.

I thank you very much for the honour you have done me in asking me for the second year in succession to dine with you and I am very glad that my engagements have made it possible for me to be here this evening. I am also much indebted to your President, Mr. Varma, for the very kind and flattering remarks he made when proposing the toast of my health and to you, gentlemen, for the manner in which you received that toast. I do not speak anything but the truth when I tell you that I have always had a great admiration for engineers and their works. Your President referred to the outstanding examples of engineering skill that are to be seen in my native land. One of my earliest recollections is of walking across the Forth Bridge before it was opened to traffic and I have lately seen the vast changes wrought over hundreds of square miles by the Grampian hydro electric scheme which incidentally has involved the driving of a great tunnel through the heart of Scotland's biggest mountain. Here in Calcutta I cannot help being constantly reminded of the fact that the house in which I live was built by an engineer—a massive structure covering a wide area and resting, I suppose, on almost the worst foundation imaginable yet it stands a monument of solidity and strength unaffected either by constant changes in water levels or by recurring earthquake tremors.

I can scarcely think that any intelligent human being is not interested in what may rightly be called the wonders of engineering and the Governor of Bengal has, perforce, to take a keen practical interest in addition to an intellectual interest in engineering matters for, in this Province, they play no small part in the general administration. The many rivers of Bengal see to that, and provide us with problems—generally emergent—of bridging and river training and, when the solution of the latter proves abortive or impossible, our Road and Building Engineers have to come into action at the gallop to make new constructions to replace those that have been engulfed and washed away. Mr. Varma had special words of praise to bestow—and bestow deservedly on the great engineering achievements to be seen on every hand in Calcutta. These I think we might call the flowers of peace and prosperity—the outward and visible signs of the perfection of the art and science of civil engineering.

I join him in that praise but my thoughts fly at once to other feats performed out in the mofussil with nothing to show for them except the fact that a township still stands safe and sound or that thousands of cultivators have harvested their crops in security and I would like to pay a tribute to the sterling work done in emergencies by engineers in the districts, often in conditions of discomfort, danger and chaos after natural calamities, working desperately against time with improvised materials and labour and every kind of markeshift. The story with which we were all, I suppose, regaled in our youth of the boy hero who lay a whole night through with his arm thrust into the breach in an embankment which threatened to inundate the fields and homesteads of his people pales into insignificance beside the actual achievements which are matters of everyday experience here.

Picture to yourselves a pitch black night with rain pouring down, a slippery embankment on the other side of which a flooded river is hurtling down rising every hour and threatening to overtop the embankment and with the overtopping to start a breach which will rapidly open out to pour torrents of water over a whole countryside. Then imagine the task of the engineer on the spot with probably nothing but a labour force of undisciplined and unorganized local coolies. I think you will join with me in saying that admirable as are the magnificent engineering feats done at leisure and after the most careful thought and planning and however much they may be a mirror of the culture of the age, yet, since it is courage that keeps a race virile and since without courage culture leads inevitably to decadence, the courage of the engineers in the mofussil and the way they rise to the occasion is a thing of which the profession may be even more proud.

While still on the subject of engineering in Calcutta I cannot forbear from mentioning the Howrah Bridge—the old one, for in October last year—1931—this wonderful structure attained, even if it did not celebrate, its Diamond Jubilee having been opened to traffic 60 years before in October 1871. It is a wonderful tribute to Sir Bradford Leslie and the engineers of those days that they should have designed and constructed a bridge which has proved capable of taking the swollen stream of modern traffic. When you consider the growth of the city and of its industrialism, to say nothing of the invention of the internal combustion engine and its application to motor vehicles with the consequent great increase in loads their wise foresight and planning seem all the more remarkable.

Ten years ago at your 4th Annual Dinner, Lord Lytton announced that Government had decided to construct a new Howrah Bridge and had prepared a Bill which would be presented to the Legislative Council later in the year.

I believe that Sir Stanley Jackson on one occasion said in public that on vacating office he expected to drive out of Calcutta over the new Bridge.

All I will say is that work on the new Bridge is as far as can be humanly foreseen definitely going to start this year and that with luck my successor may find himself driving over the new Bridge before he leaves Bengal. You will note that my native caution has returned.

As regards the rest of the Province, we, in common with other Provinces, are busily engaged on a large programme of road and bridge construction which will not only provide a great deal of employment and stimulate trade but, it is hoped, by providing increased facilities for communications and marketing will permanently raise the general economic level of the Province.

Our Irrigation Engineers are at work on projects for supplying water to tracts which have suffered from drought owing to the decadence of rivers or other causes and a considerable measure of success has attended one important project of this nature which I had the pleasure of opening at Rondia in September 1933—the Damodar Irrigation Canal.

The first year of the working of this Canal showed an enhanced paddy outturn, both of grain and stalk in the lands which took the water while in those lands in the same locality which did not do so the paddy crop either failed altogether or was extremely poor.

Now, gentlemen, before I resume my seat I should like to congratulate you on being so fortunate as to have Mr. Varma as

your President, and to say how appropriate it is that you should have accorded this honour to him for I think I am correct in saying that he might well be regarded as the Father of your Institution.

It was he who started the first Association of Engineers that ever existed in India when thirty years ago he established "The Engineers' Association, Punjab," and he was largely instrumental in founding the larger all-India body which is now so firmly established.

His personal career has been as distinguished as it has been long. It started as far back as 1898 (I begin to think of the Howrah Bridge) and he rose to the highest post possible, that of Chief Engineer and Secretary to the Punjab Government, Irrigation Branch, before he was translated some four years ago to the Public Services Commission.

In honouring a man like this you have done honour to your selves.

Gentlemen, I thank you again for your very kind welcome and hospitality and trust that I have not taken up too much of your time.

Sir Guthrie Russell in proposing the Toast "Our Guests" said :—

Your Excellency, Mr. President and Gentlemen,

A year ago I had the honour of presiding at this dinner and proposing the health of the guest of the evening, His Excellency the Viceroy. This year, though I have be n degraded two places on the table, the onerous task of proposing the health of our other guests has fallen on me. At a recent dinner in Delhi I heard a story, and though some of our guests to night may have been present at the same dinner, I am taking the liberty of repeating that story, as it very accurately describes my position this evening.

During the Great War, I think, in Gallipoli, a Company of British troops was driven back from a section of the line it was holding. A Staff Officer dashed up and instructed the Company Commander to re-take the section and restore the front line. The Company Commander hesitated for a moment and turning to the Staff Officer said "I shall do my best but you must remember that I am not a real soldier. I am only an Ironmonger." I, Sir, am not a real orator. I am only an ordinary Engineer. My position is made all the more difficult following the eloquence of Your Excellency and that of our President, and coming before what will

I know be the polished phrases of those who are about to follow me, all I can say is that I shall do my best like our friend the Ironmonger.

I think we, as an Institution, have reason to congratulate ourselves that we have gathered together this evening so many distinguished guests. Their names are household words not only in Bengal but throughout India. If I were to extol the merits of them all I would merely be telling what you know already they are men that count in Government, in trade, in Industry, in Banking, and in the learned professions. I would merely crave permission to make special mention of one, and I have got to be very careful in what I say about him as it is he who has undertaken the task of replying to this toast. I specially wish to thank Sir Brojendra Mitter for undertaking this duty. As originally arranged Sir Nipendra Sircar should have made this reply, but at the last moment he was prevented from doing so and Sir Brojendra Mitter like the sportsman he is has taken his place.

There are some here to night who must have had the privilege of hearing Sir Brojendra as Leader of the House in the Assembly replying to a debate, a debate during which to all appearances he had slept the whole time. So far as I have noticed this evening he has been awake so I feel quite sure that Our Guests in having Sir Brojendra to answer for them are in safe hands.

Gentlemen I ask you to rise and drink to the health of our guests coupled with the name of Sir Brojendra Mitter.

The Hon'ble Sir Brojendra Mitter, in reply, said:—

Sir, this is not the first time that I have had the pleasure of enjoying your hospitality. I deem it a great privilege to be called upon to respond to the toast proposed in such felicitous terms and so warmly received. On behalf of my fellow guests and on my own behalf I thank you most heartily for the generous repast and for the opportunity of meeting so many distinguished members of the Engineering profession, some of whom I can claim as old friends.

Sir, this is a remarkable gathering. During the last fortnight we had, in Calcutta, a notable muster of eminent scientists, first, in connection with the Science Congress, and then, in connection with the inauguration of the National Institute of Science. The majority of those eminent men are heroes of the laboratory, seeking to wrest from Nature her secrets, while the present Company consists of men of mettle who daily apply the discoveries of science to practical use.

We, in Bengal, are confronted with such a diversity of problems which you gentlemen must solve, that we are particularly happy to meet you. Our mighty rivers must be spanned; our dying streams and broad marshes must be reclaimed; Roads and Railways must penetrate the interior, not in competition, but in co operation, to carry our produce to the market; vast tracts of the country must be protected from devastating flood or saved from the blight of drought; our water courses must be used for quick transport. And, despite the step motherly treatment of the Railway Board, coal must be won from our mines. All this is necessary for our economic development, and we constantly want your help. In this obscure and neglected corner of India your presence in such number inspires hope in us.

Sir, in these days no two men can meet without talking about the Constitution. I wonder, gentlemen, whether you even thought of one of the paradoxes of our public life. Engineering problems are among the foremost in this country; yet in our public bodies, be they Legislatures, District Boards or Municipal Boards, there are hardly any engineers. Were I a dictator, I would have introduced occupational franchise into the new Constitution.

Sir, reference has been made to the Howrah Bridge. I cannot resist the temptation of relating an incident to you. At a recent symposium of distinguished Scientists, the Howrah Bridge came in for discussion. Why was there so much timidity, such differences of opinion and such inordinate delay? Various theories were propounded from relativity to finance. The theory, however, which secured general assent was that in Engineering Schools, co education had not yet been introduced. You may well ponder over it for the benefit of future generations of Engineers.

Sir, I would have loved to touch upon many other matters of interest to you. But last evening I chanced to meet Sir James Pitkeathly at a popular restaurant. He was in a hilarious mood. He solemnly admonished me not to fire the patience of the Diners to-night. I must therefore conclude by wishing the Institution of Engineers a long life of prosperity and continued success.

The Hon'ble Sir John Woodhead in proposing the Toast of "The Institution" said:—

Your Excellency, Mr. President and Gentlemen:

It was early in December last that Mr. Atkins, on behalf of the Council, invited me to attend the 15th Annual Dinner of the Institution of Engineers and accompanied that invitation with the request that I should propose the toast of the "Institution." At the time I thought that the Council and Mr. Atkins were a little

rash in asking me to undertake that task and the more I have thought over the matter during the last few days the more convinced I am that Mr. Atkins, whom I personally know as a most careful man, has been guilty of an error of judgment. The whole trouble, gentlemen, is that I am not an engineer, neither born nor made, and surrounded as I am by engineers to-night—and not only engineers but engineers who possess the hall-mark of Membership of the Institution—I feel a certain amount of trepidation in speaking to you of engineering in general and your Institution in particular.

As Mr. Atkins appeared to be largely responsible for placing me in this rather difficult position, I naturally appealed to him for assistance. I hoped that he would tell me what to say—speakers are often told what they should say—and of course I was hoping for some novel suggestion, something by which I could hold your attention, for instance perhaps something about digging for gold in the streets of Calcutta—Mr. Atkins has done a lot of digging in Calcutta—or a true story about the Dhakuria Lake Monster. But no, do you know what he sent me, a book containing the constitution of the Institution, several volumes of the Institution's Journal and other papers, and suggested that I should read them. And, gentlemen, would you believe it, I have read some of them and what is more I have brought some of them with me to night so that I can refer to them if necessary.

Constitutions are usually dry things—and during the last 3 years or so I have seen sufficient of constitution making to last me my life time—but there were one or two items in the list of objects of your Institution which seemed to strike a note to which I, although not an engineer, could respond! As Finance Member of a province which persists in disclosing a deficit I was particularly attracted by object (l) "*to accept any bequest gift, donation or subscription,*" also by object (o) "*to borrow or steal*"—no I apologise not to *steal* but to *raise*—"*to borrow or raise money,*" again by item (t) "*to make, accept, endorse, execute, issue and negotiate promissory notes, bills of exchange and other negotiable instruments.*" Gentlemen, it was news to me to discover that "low finance" and "high engineering" were so closely connected. Having made that discovery I read a little further and found that the Institution is authorised *to attach*—a most significant word—to itself persons called *subscribers*. According to the Constitution, these subscribers pay an annual subscription of Rs. 50/- but are not permitted to vote—a most excellent arrangement, and one which speaks volumes for the constitutional acumen of your founders.

And, gentlemen, having found points of contact between finance and engineering I feel more at my ease and not quite so nervous about speaking of engineers and their profession.

During the last century men of your profession have contributed more perhaps than those of any other to the material progress of the world; and we, in India, this land of great distances, of large tracts of country over which the rainfall is uncertain, of mighty rivers, of extensive plains, and of high mountain chains, have special reasons to be grateful to the members of the engineering profession. A hundred years ago a journey from Calcutta to Delhi occupied several dreary weeks, to day it can be accomplished in a few hours by an aeroplane. A hundred years ago it took months to communicate with and receive a reply from the countries of the west, to-day thanks to the marvellous development in wireless telephones, a person in Calcutta can converse with his correspondent in London thousands of miles away. A century ago many parts of India were liable to famine, to day the danger of famine has largely disappeared owing to numerous irrigation works. Less than 50 years ago electrical engineering was in its infancy, to day electricity is put to a thousand and one uses in the service of mankind. That, gentlemen, is a magnificent record for any profession.

But, gentlemen, there is still great scope for engineering ability and particularly so in India which from an engineering point of view is still largely undeveloped. We require engineers skilled in reinforced concrete for our buildings and bridges; highly qualified electrical engineers for the numerous electric supply organizations that are springing up; expert road engineers, for the next decade will certainly see a large extension in our system of roads; fully qualified engineers for the development of our industries: engineers for our railways, the best qualified engineers to tackle the many problems presented by our rivers, particularly by the extensive river system of this province; in short, we require expert engineers in every department of our national life.

We not only require engineers but we require the best engineers and that leads me on to your Institution for the main objects of that Institution are—

(i) first to promote and advance engineering in all its branches in India.

(ii) secondly to maintain a high standard of efficiency and professional conduct among engineers in this country.

We want the best and the part which an institution of recognised authority like yours, including as it does among its members the heads of the various branches of the profession, plays in securing the best cannot be exaggerated.

Although your Institution has only been in existence for about 15 years, it has already established itself as the acknowledged authority in engineering matters in this country and the guardian of sound engineering traditions. Your membership, now over 1,200, is a sure sign of an established position. You have been successful in improving the standard of instruction in many engineering colleges and schools and above all you have been able to maintain a high standard for admission to your Institution. I congratulate you on the success which has attended your efforts in the cause of engineering in this country and feel sure that your Institution will continue to exert a powerful influence in assisting India along the path of sound economic development.

Your Excellency and Gentlemen, I will now ask you to join with me in drinking to the prosperity of the Institution of Engineers.

Col. F. C. Temple, in reply, said :—

Your Excellency, Mr. President and Gentlemen :—For a long while it was the custom that this toast of the Institution so ably proposed by Sir John Woodhead should be replied to by the senior Past President present. So much was it the custom that on at least four occasions the person on whom the honour has fallen has expressed regrets that the person who should have done it was unavoidably absent. This being so it took me by surprise when I received a letter informing me that the Council (rather rashly in my opinion) had selected me for the honour. I think they were rash for as far as I am aware none of them have ever heard me attempt to make an after dinner speech. But accepting the request of the Council as in the nature of a command, it appeared advisable to look up what and how much had been said by those replying to this toast at previous dinners. Those who are possessed by the microbe which goads men to inflict their opinions on others, are obliged by editors and printers to count the number of words in which those opinions are expressed. It was therefore natural to estimate the number of words used by previous responders to this toast. This did not prove a great deal of help for they have varied between 700 and 2,000. None has so far achieved the brevity of the man who at a writers' dinner had to reply to the toast of literature and said "This is a sad subject. Homer is dead, Virgil is dead, Shakespeare is dead, Milton is dead, and I am not well"

and sat down. I too shall not equal that but I hope to be inside 2,000.

At least two of my predecessors have said that they were engineers and would rather build a bridge than make a speech. There are worse things than building a bridge, even if an earthquake does come to twist it into all manner of shapes, and leave the builder open to the remark made to me by H. E. The Viceroy after he had been over some of the damaged bridges "You certainly built some very odd bridges." But gentlemen there are worse things than making a speech. One is, to try after being fifteen years out of practice at it, to write a note that will induce a Government Secretariat to spend money. In doing that the only safe thing is to remember the advice given by a C.R.E. to his Garrison Engineer in Fort William in 1906, "If you want to get a project sanctioned, you must remember that the higher authorities, even though they may have called for that project, find their minds a complete blank about it when it comes up, and must be told its whole history and all about it again. Above all remember that the senior officer who will give the final order on it, has entered his second childhood, and has only the intelligence of a child of two."

It has been suggested to me that you may like to hear something of what has been done by engineers in connection with the earthquake. First and foremost we must offer our tribute of praise to the way in which the B.N.W.R. engineers reopened their lines and the District Board Engineers with the help of the P.W.D. and some Royal Engineers opened their roads to traffic. Theory and redtape were both left to take care of themselves. The policy was to open up by any means however odd things looked. Each man did the best he could on the spot and did it successfully. It is true some risks were taken. In more than one screwpile road bridge a pile had sunk three or four feet making a drop in the bridge with a slope of 1 in 7 or 1 in 8 and the three or four longitudinal girders were each held in place by two 5/8 bolts at each end. As long as the bolts were not actually cracked, buses were allowed over the bridges for two or three months. And the risks were justified for no accident occurred. And before the rains almost all the railway was reopened over rebuilt bridges and all the most important roads were made passable either by rebridging permanently or temporarily, or by providing ferry boats capable of taking motor cars.

The total number of railway bridges damaged or destroyed and rebuilt was over 300, and the total number of road bridges damaged or destroyed must have been about 1,000. We do not yet

know what is the real total which will have to be replaced because earth movements have gone on since the earthquake and are still going on. Many masonry bridges which appeared in February to be safe have failed since. One big one fell down without warning in May, and several had to be taken down. At least ten more must be taken down now, and over 30 more are being watched with suspicion. Buildings too which appeared capable of repair before the rains have had to be condemned since. Meanwhile the earthquake has enriched the language in some respects. The plural of debris is debrises and of fissures fissuries, and anything that happened before it is pre-quack. And some material good has come of it too in that the people who were crowded at 44 families per acre on 14 acres in the Chowk at Monghyr will be spread out over 41 acres, and the most congested part of Darbhanga, owing to the Maharaja's munificent gift of 5 lakhs will be replanned on much more spacious lines.

Turning now from outside topics to the Institution and its affairs, the year just past is a red letter year because for the first time the Institution has cleared off its overdraft at the Bank. This is due not only to numbers having gone up to about 1,250 (it is not so very long since we were wondering how soon we should pass the 1,000) but also to the fact that members have been paying their subscriptions better, though still not as well as we could wish. The standard of qualification is still being strictly and jealously maintained.

Interest in the Institution abroad is shown in letters received and also applications for membership occasionally received from people in foreign countries.

The number of technical papers submitted by members is still lower than we might wish. This may be due to the depression and the comparatively small number of new works being executed. But every engineer must be encountering difficulties and an account of methods by which they were overcome would be of great value to others. It is to be hoped that the writing microbe which I mentioned previously may attack more members and inspire them to put their experiences at the service of their fellows. I am not preaching what I do not practice for up to now I have I believe inflicted on the Institution more technical papers than any other member. Papers need not be long. A short account of an unusual difficulty ingeniously overcome or of a temporary failure turned to success is likely to be most acceptable.

In conclusion I tender the thanks of the Institution to Sir John Woodhead for the pleasant things he has said about it and to all for the way in which they responded to the toast.

OPEN-END TYPE TUBE WELLS

BY

H. G. TRIVEDI, Associate Member.

It is a well known fact that the yield from ordinary wells is extremely limited, the reason being that water only percolates vertically through the floor so that there is a limit to which depression head can be allowed to operate on the well, as this floor generally consists of fine sand in these Provinces. It is also well known that if a well rests on "mota" or a thick bed of clay and that if this bed is pierced through and the water bearing strata below tapped, considerably greater quantities of water can be obtained. This increased yield is due to a sort of cavity formed under the clay bed, which then acts as a roof over the cavity.

Such wells may be found dispersed all over the Province, but no scientific investigation seems to have been carried out to find out the nature of the cavity formed. Actually what happens in such wells is that, when the clay bed is pierced and water is pumped, a good deal of sand rushes with the water into the well in the first instance. This sand has to be removed and more sand drawn in until the required quantity of clear water is obtained. By a repetition of this process on a large scale it is possible to obtain as great a quantity of water as desired, depending of course on certain conditions.

It was with a view to ascertain these conditions and other limitations consequent on this particular type of well that two experiments were carried out, one at Unao and the other at Hathras. The strata at both these places was very poor from the point of view of ordinary strainer tube wells and it was indeed fortunate that these experiments proved to be successful, for they laid the foundations of the water works at both these places, one of which viz. the Unao Water Works has been functioning successfully since 1927, while Hathras has got a battery of five tube wells ready for the inauguration of its water supply in the very near future.

Writer was concerned with both the experiments and gives below a brief description of the observations made and conclusions arrived at for what they are worth :—

1. *Unao Water Supply.*—A 7" tube well with strainers had already been constructed for Unao as long ago as 1915 but as the Municipal Board could not find money to inaugurate their water works at the time, it was lying unused for many years with the result that when the Board again moved for its water supply in the year 1925, this well, when tested, hardly gave 90 gallons per minute. The strata at this place consisted of very fine sand and as the strainer well installed in this strata had deteriorated so much at this place and as trouble had already been experienced in similar wells at other places, it was decided to carry out an experiment to find a suitable type of well for such localities. This place was specially suited for such an experiment due to the fact that a very thick bed of clay was available to act as a roof for the cavity, so necessary to obtain water in any large quantities.

A site for the experimental well was selected close to the existing 7" tube well and sinking operations were started in the beginning of November 1925. A 12" casing was sunk to 179 feet below ground level. The strata encountered as may be seen from the chart attached (Plate 1) consisted practically of one thick bed of stiff clay overlaying 35 feet of water bearing strata.

Further reference to Plate 1 will show that the clay bed extends to 143 feet from ground level, below which there is a 7 feet bed of sandy clay with pieces of bajri and kankar, then comes about 3½ feet of very fine sand and finally 24½ feet of fairly medium sand. This completes the water bearing strata, none of which is good enough for the ordinary commercial type strainers.

The bore was completed early in January 1926, when arrangements were made to blow out the sand by means of compressed air.

The first object was to find out the best position, at which to keep the lower end of the casing. As the strata between 153′ 6″ and 178′ consisted of much better sand, an endeavour was made to use this as the source of supply by keeping the end of the pipe in this strata. But the result of a few days' pumping and dredging out sand showed that such a course was not feasible, as the smallest amount of water pumped out would bring in a rush of sand to plug the pipes, which necessitated the removal of eduction and air pipes and dredging out sand to clear out the plug; even a frequent repetition of this process was of no avail. The casing was, therefore, gradually drawn up and kept in the very fine sand strata and then in the middle of the sandy clay strata with practically the same results. During these processes about 279 cubic feet of sand had been pumped out. Finally the end of the 12"

casing pipe was drawn up into the clay and kept at approximately 143 feet. The progress made with this position of the casing pipe was marked and rapid.

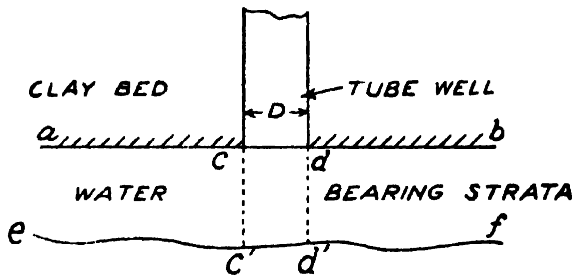
By using first smaller size eduction and air pipes a good deal of sand was blown out and a clear discharge of 100 gallons per minute with a depression head of only 13 to 14 feet was established. Finally a 6" and 2" eduction and air pipe set was lowered in the well and by means of it a considerable quantity of sand was blown out with the result that discharge gradually increased to 230 gallons per minute under a depression head of not more than 23 feet. The water obtained finally was so clear that not even a grain of sand was to be traceable in it, which is remarkable when it is considered that this quantity of water was being given up by a fine sandy clay strata.

Very careful records were kept of the amount of sand pumped out and frequent observations were made to find out the depth of the cavity. This depth was, however, extremely small, in fact it never was more than 2 or 3 inches. Therefore considering the 1,670 cubic feet of sand pumped out it is evident that this cavity must have extended over a very large area under the clay bed. If an average depth of 2 inches is taken for this cavity it would seem that an area having a diameter of approximately 200 feet must have been affected. All this is, however, guess work, as the actual condition underneath cannot be known by a single experiment like this. Even if a number of borings are made in the supposed affected area and careful measurements taken of the depth of cavity at these points it is hardly to be expected that this area will be found to be a circle with the tube well as its centre. Such information, howsoever important from a theoretical point of view, is fortunately not essential for practical purposes.

There is another point of view, which strikes the writer and it is this, that the fine sand or sandy clay, when it is under pressure, does not release its water so easily as when some of its pressure is released, as for instance in this case, by blowing out a quantity of sand, thus making it possible to yield a large quantity of water without difficulty. Immense work in this direction awaits research, but it requires a good deal of time and money, none of which is easily available with Government specially in these days of depression.

It is possible to give a mathematical explanation of this small depth of cavity if it is assumed that the flow under ground is

horizontal especially when a comparatively small area is considered.



For, let 'a b' be the lower surface of the clay bed to which the end 'c d' of the pipe of diameter 'D' extends. Let 'e f' be the surface of the cavity just below c d. Now if an imaginary cylinder 'c c′ d′ d,' just below the mouth of the pipe is considered, it may be assumed that the velocity near 'c d' and just below it is the same. Let this velocity be 'V.' Now if 'H' be the depth of the cavity, we have the amount of water entering the pipe at 'c d' equal to the amount of water entering the lateral surface of the cylinder 'c c′ d′ d,' neglecting the small amount of water entering the bottom 'c′ d′.'

Thus $\frac{\pi D^2}{4} \times V = \pi D \times V \times H.$

From which $H = \frac{D}{4}$

In the case under consideration 'D' was 12 inches. Therefore the depth of cavity works out to be only 3 inches which is fully borne out by the experimental observations.

Plate No. I gives the details of the strata passed through during the sinking of the casing, while Plate No. II shows the permanent arrangement of the tube well, with the air-lift pump on the 'outside' system.

Appendix A gives details of the gradual development of the well. In this connexion it will not be out of place to mention that when the development was nearly complete, an attempt was made to fill the cavity from which one thousand six hundred and seventy cubic feet of sand had been blown out with brick ballast ¼″ to 1″ size, but most of this ballast was brought up by the air in the process of pumping and whatever remained choked the cavity

rather than roll out, as was hoped, to the sides to act as support for the roof of the cavity.

The well was fully developed by the first week of March 1926, when it was subjected to a three days' continuous day and night test from March 8 to March 11, 1926 with the following results:—

Depression in feet.	Discharge in gallons per minute.
15'	164
19	200
21'	221

Plate III shows these results graphically.

Water obtained was practically free from sand and it was also proved, chemically and bacteriologically, fit for domestic use. The report of the Government Analyst, Agra, to whom the samples were sent for analysis is given as appendix B.

The total cost of this experiment, which resulted in a complete and a successful tube well did not exceed Rs. 5,600 against the estimate of Rs. 6,650 -.

Hathras Water Supply.—There being a great scarcity of water and most of the wells in Hathras being brackish, the question of a potable water supply to this important industrial town had been under consideration for a very long time. As far back as 1915 a trial bore, details of which are given on Plate No. IV, was sunk to 313 feet below ground level. But as any good or sweet water bearing strata could not be found, it seems that the water supply proposals were kept in abeyance till in 1926, just after the successful completion of the Unao Tube Well, this question was taken up in right earnest again.

A site was selected away from habitations and where the few shallow wells that existed yielded sweet water and the work on boring operations was commenced about the end of July 1926. As however every possibility was to be explored to find a suitable and sufficient depth of water bearing strata, the bore was carried down to 426 feet below ground level by the end of February 1927, though in the estimate there was a provision for only 260 feet.

This search for a sufficient depth of water bearing strata was necessary due to the fact that the pure cavity type well laboured under two very grave defects, which will be mentioned later on

and it was considered advisable to complete this well with a type of brass strainers, which from their very construction might be considered to have a longer life than the ordinary copper mesh or wire wound strainers in general use in these Provinces. Luck, however, did not favour this search and once again experiments with cavity wells were started.

If a reference is made to Plate No. V, wherein is shown the different strata passed through in this boring, it will be seen that any of the strata between 348′ & 359′; 310′ & 328′ & 273′ & 287′ could with advantage be utilised for the supply, but the most suitable one was apparently the last one *e.g.* 273′ to 287′ as it had over 170 feet thick roof of very stiff clay above it.

The development of the well was a very prolonged operation in this instance. First the strata Nos. 348′ to 359′ & 310′ to 328′ were tried and it took from about the beginning of April 1927 to about the beginning of July 27, to obtain fairly satisfactory results in that a discharge of about 200 gallons under a depression head of 40 feet was established. During these operations over 1,500 cft. of sand was blown out. Occasional measurements of the depth of cavity were also recorded and it was never found to be more than a few inches.

As the depression of 40 feet was considered extremely high, the 15″ casing pipe was drawn up further to the strata 273′ to 287′ and after a few experiments by keeping its end at different positions, it was finally fixed at 273′.

The development of this strata took nearly two months *i.e.* from 25-7-27 to 22-9-27. This strata too did not produce any better results than the others for it also yielded about 200 gallons per minute with a depression head of 40 feet or a little over 100 gallons with a depression head of 21 feet. Plate No. VI depicts the discharge, obtained, graphically. Amount of sand blown out from this strata was 710 cft.

In Appendix C is set out in detail the way in which development took place in the last strata, while Appendix D shows the analysis of the water as carried out by the analyst. It is evident that the strata is extremely poor in its water bearing quality and it was decided to limit the depression head to about 20 feet and discharge to 100 gallons per minute in the final and permanent arrangement for the pumping plant.

Incidentally this experiment proves the great superiority of the air lift over any other type of pumping plant for tube wells in that

there is no limit to the depression head that can be put on a well provided the well is deep enough for adequate submergence of the air pipe and that no damage can occur due to the inflow of sand as no working parts of the machinery come in contact with it.

Conclusions.—These experiments have conclusively proved that with this type of well, provided circumstances are favourable, even the poorest strata, in which nobody would even think of putting in the ordinary commercial type strainers, can be made to yield a large quantity of water with ease. There are, however, two very great drawbacks in the pure cavity type of well, which tend to limit its utility and universal application.

One drawback is that there must be a very thick bed of stiff clay over the water bearing strata to ensure the stability of the cavity, otherwise there is a great danger of the upper strata sliding down, which may eventually cause cracks in the buildings of the neighbourhood and result in consequent suits for the recovery of damages.

The other great drawback is the fact that, in these Provinces as a rule, just below the stiff clay bed, is found only very fine sand or sandy clay followed by medium or coarse sand much lower down, which latter, as has been conclusively proved by these experiments cannot be fully utilised in the pure cavity type well and so reliance has to be placed on the strata just below the clay bed, which by its very nature is extremely sluggish in yielding its water.

Further development has, however, taken place since, and both these difficulties have now been completely surmounted by a new type of tube well which the writer hopes to describe on some future occasion.

APPENDIX "A."

Date.	Size of eduction & air pipes.	Discharge gallons per minute.	Depression head in feet.	Amount of sand pumped out. C.ft.	REMARKS.
7-1-26				30	Sand plug removed.
22-1-26 to 24-1-26	2" and ¾"	15 to 20	7 to 8	15	
25-1-26	3½" & 1¼"		28	30	Discharge not continuous.
30-1-26	2" and ¾"		11	31	
1-2-26	Do.	15 to 20	9	60	Depression head 9·5 ft.
2-2-26	Do		9	1	Water clear in the end.
3-2-26 and 4-2-26	2½" & ¾"	40	24	112	Water clear in the end.
9-2-26	3½" & 1¼"	85	14	173	Casing pipe raised into clay.
10-2-26	Do.	100	14	40	
11-2-26	Do	100	14	16	Water clear.
12-2-26	Do.	100	14	20	
14-2-26	6" & 2"		25	504	
15-2-26	Do.	180	22	193	
16-2-26	Do.		23	78	
20-2-26	Do.		21	40	
21-2-26	Do.		22	50	
22-2-26	Do.		21	20	
23-2-26	Do	to	24	60	
24-2-26	Do.		23	40	
25-2-26	Do.		22	36	
26-2-26	Do		25	4	
3-3-26	Do.		21	23	
4-3-26	Do.	230	21	36	
5-3-26	Do		21	22	
6-3-26	Do.		21	12	
8-3-26 to 11-3-26	Do.		21	24	Test pumping carried out day and night continuously for three days.

Note.—Total amount of sand pumped out-1,670 cubic feet.

APPENDIX "B."

WATER ANALYSIS FROM UNAO TUBE WELL.

CHEMICAL ANALYSIS.

No. of samples.	Copy of label on bottle.	Total solid parts per 100,000.	Chlorine parts per 100,000.	Total hardness grains per gallon.	Fixed hardness grains per gallon.	Free ammonia parts per 100,000.	Albuminoid ammonia parts per 100,000	Nitrites.
1	Sample taken after 24 hrs pumping.	60	0.8	..	..	Nil	Nil	Nil
2	Sample taken after 3 days pumping.	60	1.0	...	..	Nil	Nil	Nil

BACTERIOLOGICAL ANALYSIS.

Inoculated on	Colony count in 1 C. C.	B. Coli Test.				Remarks.
		In 50 C. C.	In 10 C. C.	In 5 C. C.	In 1 C. C.	
17-3-26		Not detected	Not detected	Not detected	Not detected	Fit for potable purposes
		Do.	Do.	Do.	Do.	Do.

APPENDIX C.

Water bearing Strata utilized 273 feet to 287 feet.

Date.	Size of eduction and air pipes.	Discharge gallons per minute.	Depression head in feet.	Amount of sand pumped out c. ft.	REMARKS.
25-7-27 to 30-7-27	2½" & 1"	40 to 47	15 to 14	160	80% sand in the beginning but water clear in the end.
4-8-32 to 7-8-32	4" & 1½"	69 to 118	29 to 24	220	50% sand in the beginning, gradually reducing to 2 or 3%.
12-8-32 to 17-9-32	5" & 1½"	180 to 204	44 to 42	320	Only traces of sand in the end.
21-9-32 to 22-9-32	4" & 1½"	109 to 125	21 to 25	10	Continuous test.

Note—Total amount of sand pumped out = 710 c. ft.

APPENDIX "D."

WATER ANALYSIS FROM HATHRAS TUBE WELL.

CHEMICAL ANALYSIS.

Number of samples.	Copy of label on bottle.	Total solid parts per 100,000	Chlorine parts per 100,000	Total hardness grains per gallon	Fixed hardness grains per gallon	Free ammonia parts per 100,000	Albuminoid ammonia parts per 100,000	Nitrites.
1	Hathras tube well.	122	20.8	...	...	Traces.	0.01	Nil.
2	Hathras tube well.	144	26.6	...	..	Nil.	Nil.	Nil.

BACTERIOLOGICAL ANALYSIS.

Inoculated on.	Colonycount in 1 C.C.	B. Coli Test.				Remarks.
		In 50 C.C.	In 10 C.C.	In 5 C.C.	In 1 C.C.	
19.9.27.		Not detected	Not detected.	Not detected.	Not detected.	Good.
18.5.27.		Nil.	Nil.	Nil.	Nil.	

Plate No I

UNAO WATER SUPPLY

EXPERIMENTAL TUBE WELL

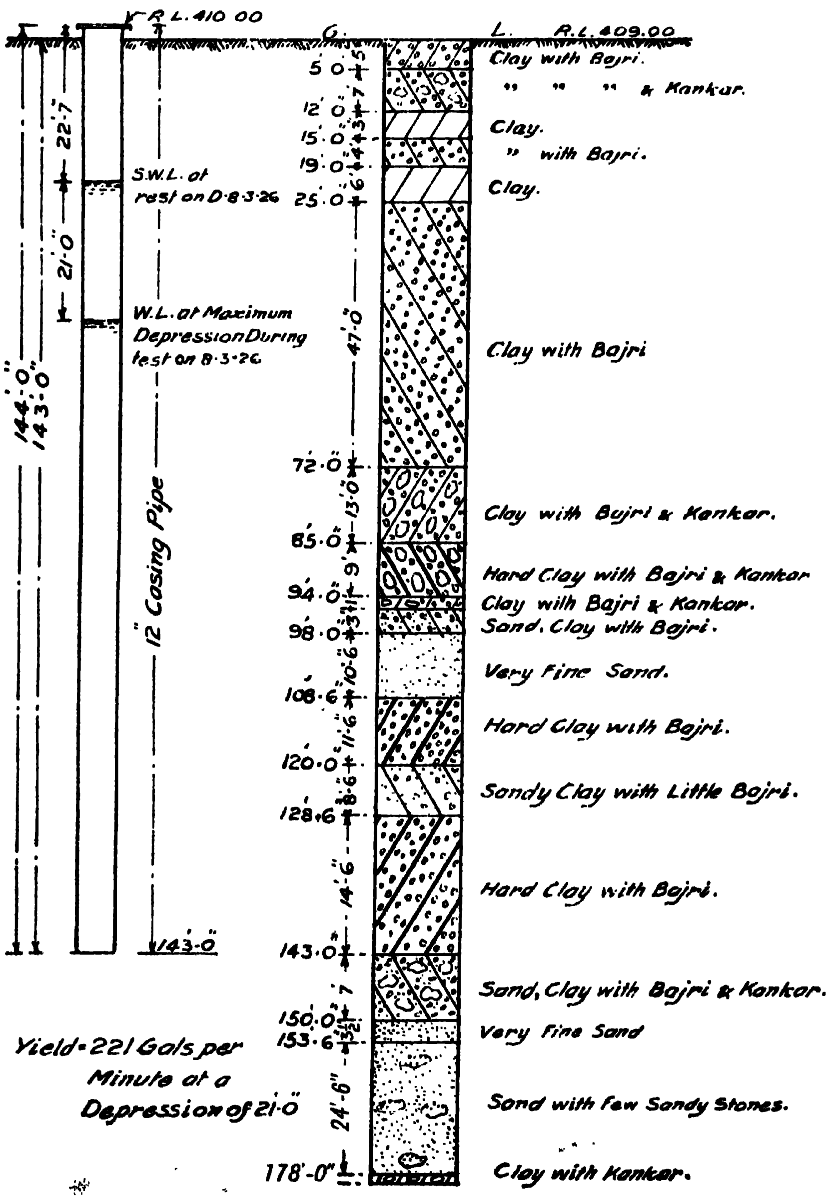


Plate No. II

UNAO WATER SUPPLY

TUBE WELL No. 2

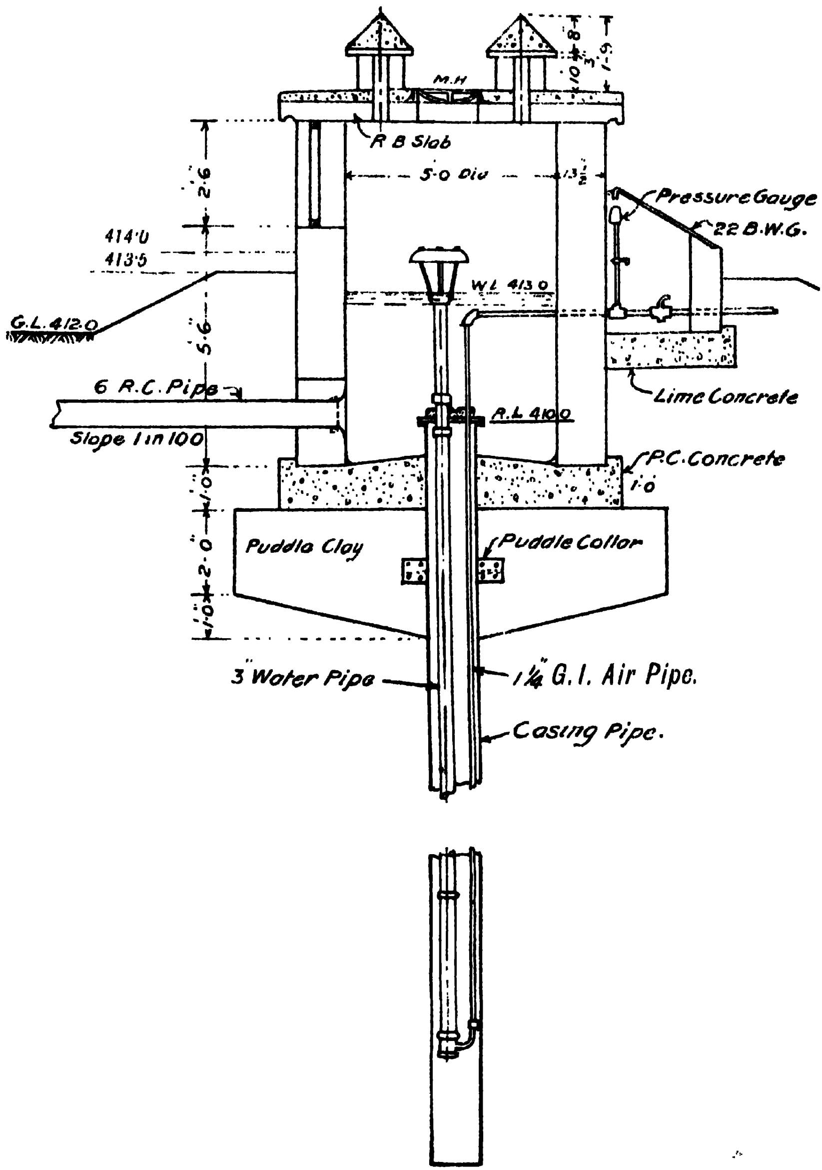


Plate No. III

UNAO EXPERIMENTAL TUBE WELL

DISCHARGE CURVE

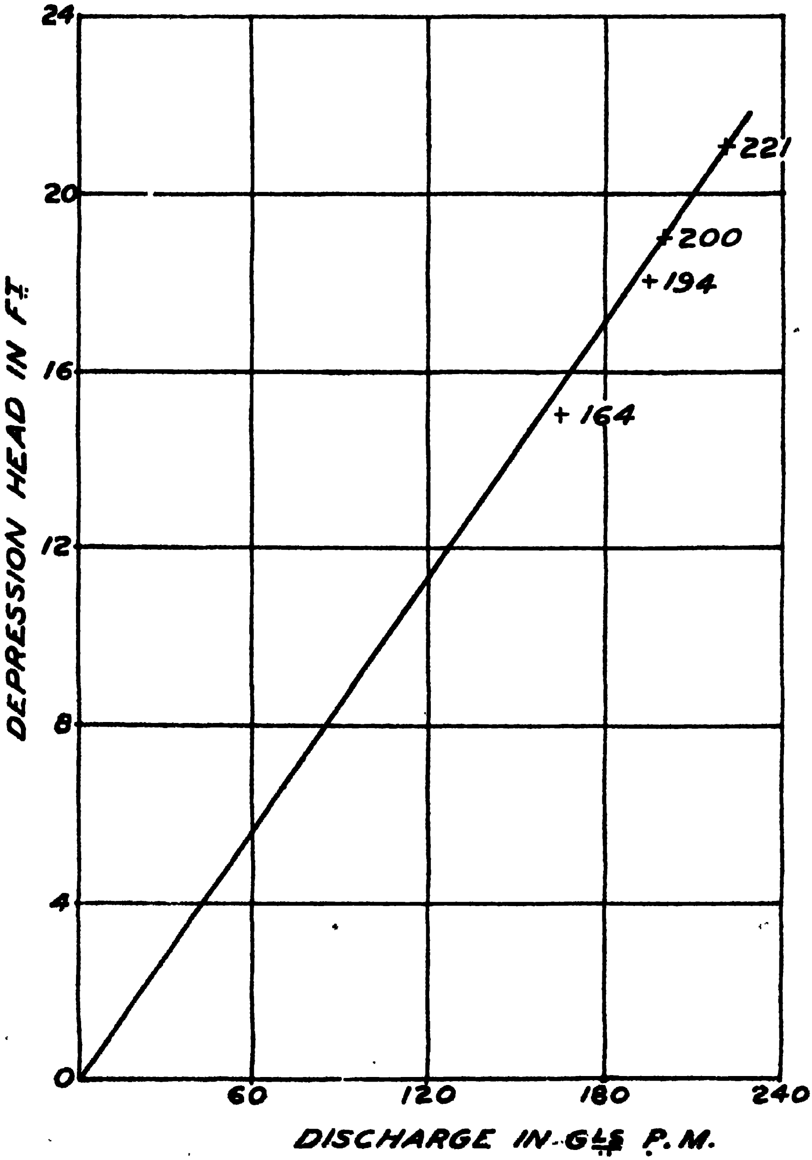


Plate No. IV

SECTION OF BORING DONE IN 1915 AT HATHRAS

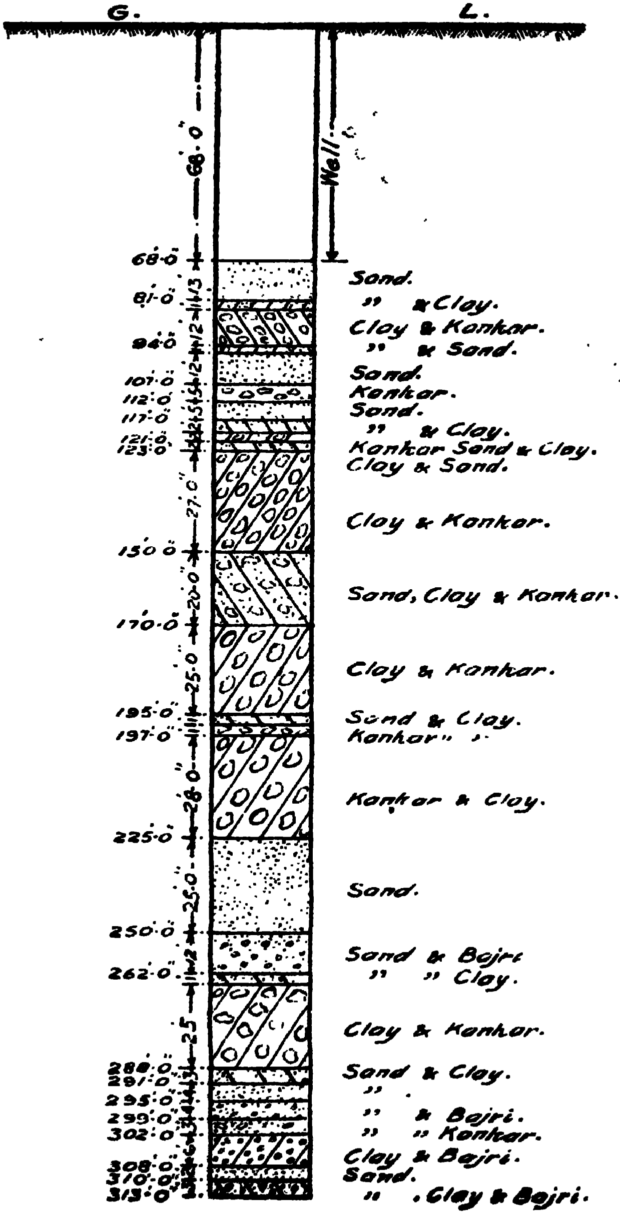


Plate N° V

HATHRAS WATER SUPPLY

TUBE WELL N° 1

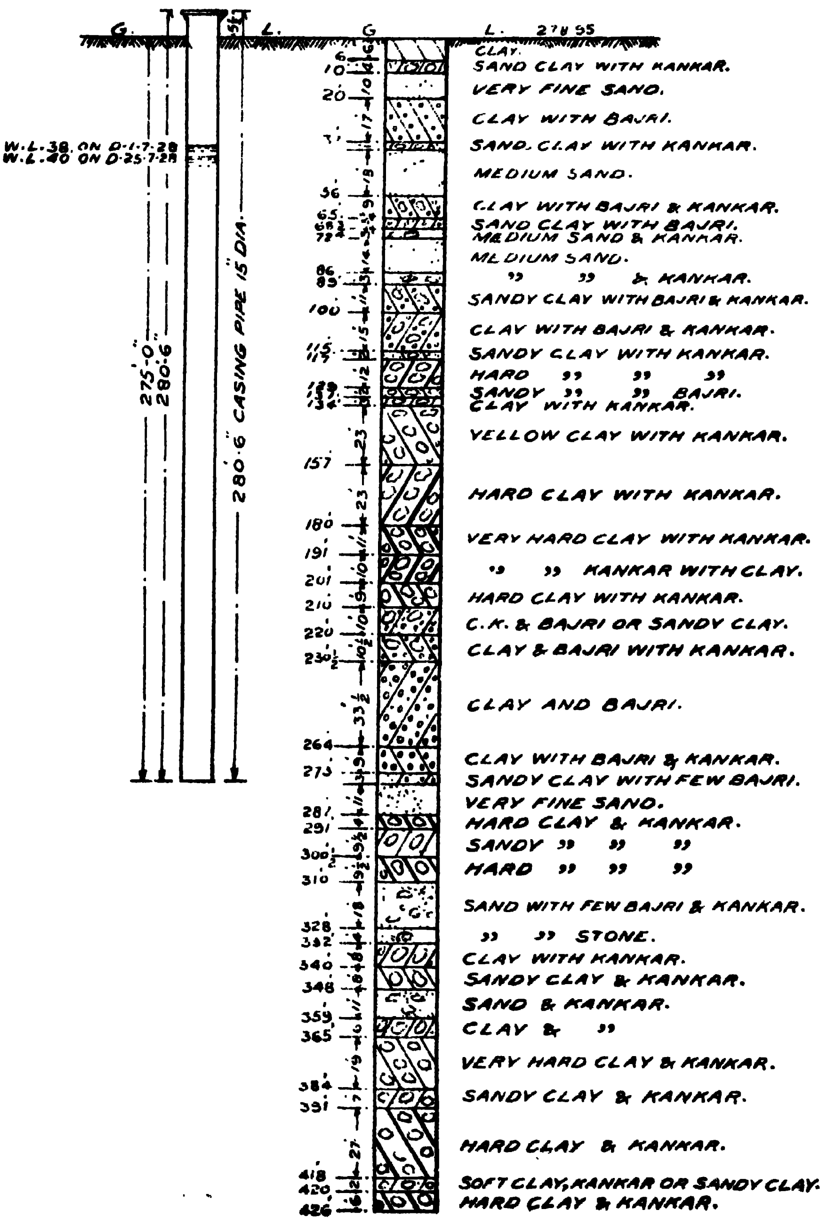
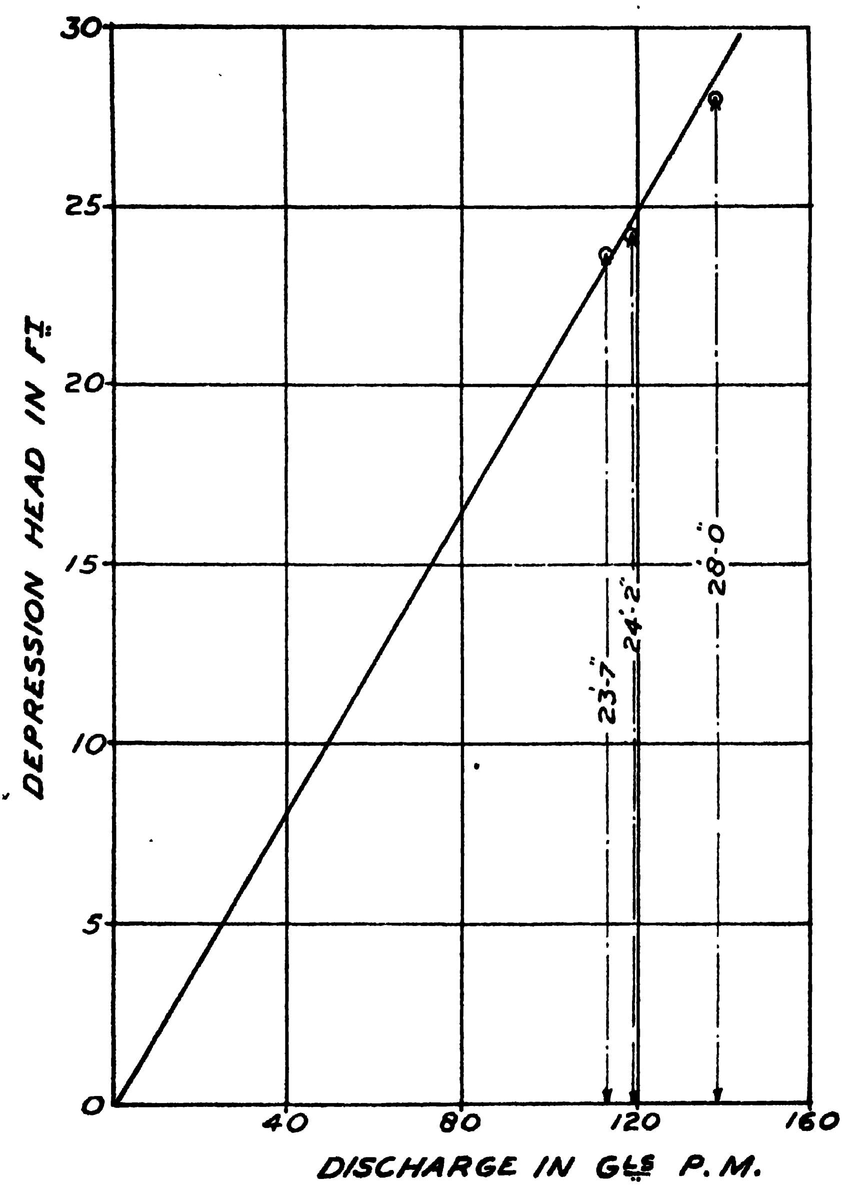


Plate Nº VI

HATHRAS TUBE WELL Nº 1

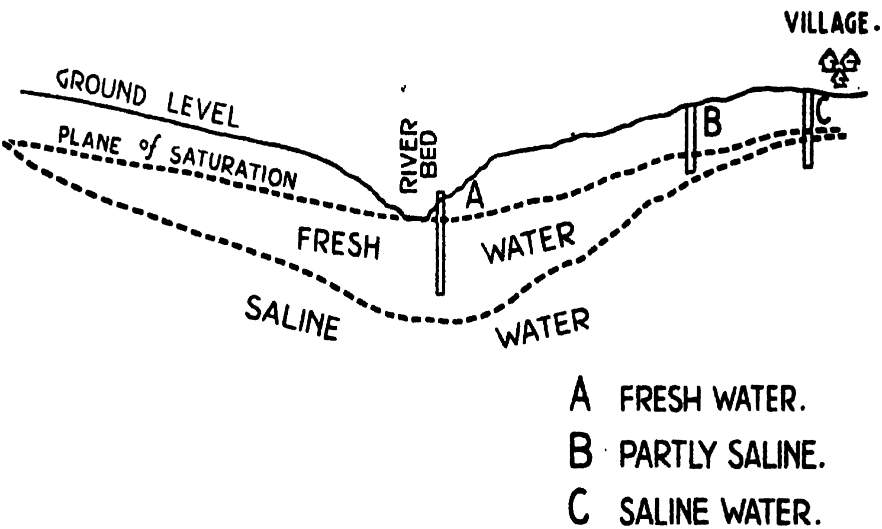
DISCHARGE CURVE



DISCUSSION ON
OPEN-END TYPE TUBE WELLS.

Mr. B. P. Surti.

Mr. B. P. Surti remarked that in connexion with Hathras Water Supply the author stated that the site selected for the wells was away from habitations. In this connexion he liked to know whether there was any river nearby as well-sinking near a river was expected to give good results so far as the quality of water was concerned, which fact could be understood from the following figure:



It had been always found that while sinking wells and putting down borings stationary ground water occurred almost everywhere below the surface at varying depths depending upon the situation of water bearing strata. Ground water level generally appeared to be nearer the surface under a river bed than elsewhere in a given area. The percolation through this source took place for the whole period of monsoon with the result that ground water attained almost the same level as that of the river and so much so that even after the river bed had practically dried up the seepage of water continued for a very long time. The constant

washing action of the subsoil under the river practically removed all saline matter from immediately beneath the bed. Hence the best place to sink a well should be near a river and not too far away specially in districts where the alluvial deposits were impregnated with saline water giving brackish taste. The chemical analysis of water from Hathras Tube Well showed a very high percentage of chlorides. It was presumed that those results were of a sample of water drawn at 273 ft. depth. It would be interesting if the author could give the results of water samples taken at different levels. Mr. B. P Surti.

Mr. B. SAROUP remarked that Mr. Trivedi's paper was very interesting indeed. The only objection was the cost involved in developing Open end type Tube Wells. On reference to page 37 it would be found that the well cost Rs. 5,600 . The strainer type Tube Wells were very much cheaper, but the difficulty was that there was no strainer in the market that would keep fine sand out. The usual metal type strainer had slits or holes, which, however fine they might be, would pass a certain amount of fine sand, and it was due to this reason that deep borings had to be made, in order to find the sand that would be coarse enough for the strainer to keep out. This difficulty had been completely overcome by a new type of Ferro Fibrous Strainer, which he had invented. In that strainer he used coir fibre rope or mat, as the straining medium. From a sample it would be seen that light did not pass through the strainer, consequently it was obvious that no sand could possibly go through it. At first sight it might appear that the strainer would not be sufficiently porous to pass water through. He had carried out tests with a view to determine porosity of the strainer and could safely say that his strainer was very much more porous than the usual metal strainer. From a piece 4 ft. long having an internal diameter of 2" connected to the suction side of a Centrifugal pump driven by a 2 in. Bernard Engine and pumping water from a tank, he obtained a discharge of 100 gallons per minute. On another test, he could obtain from a strainer 2 ft. diameter with a total straining surface of 8 sq. ft. a discharge of 200 gallons per minute with a depression of one inch only while pumping from a tank. Water in his strainer did not pass between the two adjacent coir ropes. It passed through the ropes actually, consequently there was no possibility of the sand going through. He had lately completed a Tube Well for the Public Health Department, Punjab, at Hoshiarpur, where conditions were rather peculiar. The only stratum available was from 60 to 70 ft. below ground and it consisted Mr. B. Saroup.

Mr. B. Saroup.

of very fine sand mixed with clay. He understood that a Tube Well was sunk and fitted with a metal strainer and that it got choked up in a very short time. It was then decided to sink a 12 in. Tube with four auxiliary tubes each 4 in. diameter. The well was to be developed in accordance with a practice lately introduced into the Department, i.e., to pump sand and water out by means of compressed air from the 12 in. pipe and to feed gravel through the four auxiliary tubes. Pipes were lifted gradually by inches and the idea was that in course of time fine sand stratum was replaced by gravel fed through auxiliary pipes. The process of developing took considerable time and was somewhat similar to the method described by Mr. Trivedi in his paper. The question usually asked was what the life of coir rope would be in water. From the observations that he had made, he was of opinion that fibrous material such as coir did not rot so long as it remained in water and was not exposed to atmosphere. He had been able to collect authoritative information on the subject which he trusted would be of interest to engineers. Gentlemen from the South will no doubt remember that in Southern India boat planks were sewn together with coir rope and lasted indefinitely. Coir rope was used very widely on steamers and was found to be quite good in sea water. He felt sure that almost every Engineer would be able to recall some experience of coir rope and would certify to its lasting quality.

Mr. R. H. Irani.

Mr. R. H. Irani remarked that the water bearing stratum of fine sand underlying the hard clay, from which water was tapped at Unao, had a cavity formed in it of 2 to 3 inches in depth extending several feet (it was said about 200 ft.) in diameter after continuous pumping of water, loaded with fine sand for several days, eventually giving clear water at the rate of 230 gallons p.m. at 21 ft. head. It was observed that at the commencement, when pumping was first started, the area of infiltration was only 12 in. (diameter of the tube) and therefore the rate of infiltration per sq. ft. was so high that the sand was carried along with the water through the eduction tube and discharged. That state of affairs continued till a cavity with a much larger bed area was formed under the roof of hard clay, so that the rate of percolation per sq. ft. was much less than at the commencement and the sand was continued to be disturbed and pumped up by the excessive rate of percolation till a critical rate of percolation was reached, i.e., when the sand was no longer disturbed and the water pumped out was clear. If, however, after that condition had been obtained, the water were to be pumped at higher rate than 230 gallons p.m. the rate of infiltration would be more than the critical rate and

more sand would be pumped out till the area of the cavity became larger and the critical rate of infiltration reached again. Unless the layer of hard clay overlying the sand was very thin he doubted if there was any risk of its falling in; besides he doubted whether the diameter of the cavity in that case was as much as 200 ft. It should be much less at the rate of infiltration at 21 ft. head. The experiment had no doubt shown remarkable results and with further experience there would probably be a large number of such tube wells which would not only be cheaper than the strainer tubes but probably more lasting. Mr. R. H. Irani.

Mr. E. J. HOGBEN said that he had been given to understand by users of tube wells, that if a tube well of a certain size was sunk at a particular place then, after the initial pumping and when the well was established, there was a "natural" rate at which the water could be pumped from that well. If the pumping was continued at a rate well below this "natural" rate the well generally deteriorated; whilst if pumping was carried on for sometime much above this natural rate the well was usually ruined. Supposing for example that the "natural" rate for a certain well was 100 gallons per minute, then if pumping was continued at say a rate of 20 gallons per minute, or at say 300 gallons per minute, in both cases the well was very likely to be spoilt. It was quite easy to see how such a state of affairs could develop but he would like to know how one could determine for a well in a particular place what the "natural" rate of pumping should be; and also the most economical size for a well in any particular locality. Apropos of "strainers" mentioned in the discussion he recalled an incident when he was quite young which might be of interest. A tube well was sunk with a relatively expensive strainer at the bottom. It was thought that the yield was much below what it should have been. So a small charge of gun cotton (he thought it was gun-cotton, but he was not sure) with a fuse attached was dropped to the bottom of the well and duly exploded and it was almost certain that the expensive strainer was blown to pieces. The yield from the well thereafter was quite satisfactory. That incident seemed to suggest to him that the fitting of expensive and fancy designs of strainers was unnecessary. Mr. E. J. Hogben

Mr. S. K. CHAKRAVARTI remarked that Mr. Trivedi stated that the first 7 in. Tube well at Unao for water supply scheme remained unworked from 1915, the year of its sinking, till 1925. He suspected that the dormant condition of the well for ten years Mr. S. K Chakravarti.

Mr. S. K. Chakravarti.

must have been responsible for poorer yield of the tube well, viz., nearly 5,500 gallons per hour. But Mr. Trivedi did not state the yield of the same tube just after the sinking had been completed. Mr. Trivedi evidently assumed that the yield to begin with was very much more than that observed in 1925, and his assumption was probably due to the result obtained from another well bored in 1926, the yield of which was found to be very much more than that of the former one. No details for the first tube well had been given as regards its depth, the nature of stratum it was finished on, the quality and length of strainer used, the method of sinking, etc., in comparison with those of the second one; the comparison of the results alone was not surely very convincing without the governing data. He had experience of some wells lying dormant for over a year after sinking and the yield was not found to be affected thereby. The assumption that the strainers deteriorated under a considerable depth could not be very well supported as a good many tube wells had been found to work for a considerably longer period. As far as he could remember one tube well in Government House, Calcutta, was found to be almost closed up after a few years' use, and the opinions of some experts were invited as to the reason of the closing up of tube wells. Messrs. Scott & Saxby, the well-known Tube well sinkers of Calcutta, expressed their views in a meeting of the Institution sometime back that the closing up of tube wells was due to formation of some carbonates round the strainers and to a hard crust which was formed round the tube and which prevented the flow of water. The 'coir string strainer' devised by Messrs. Saroup & Bansilal of Lahore conclusively proved that the yield of a tube well did not depend on the formation of a cavity round the strainer as advocated by Mr. Trivedi. With ordinary strainers some quantity of sand must come out during pumping, especially the stuff that had been disturbed during the sinking of the tube. The quantity of sand when it was fairly coarse, coming out of a tube after a tube well had been sunk to the proper depth, did not always appear to be at all of a volume to create a cavity below the tube. He would rather believe that the less this cavity was formed, the better was the result obtained from the tube. It required a series of experiments in this line to come to any definite conclusion. He assumed that there was a permanent level of subsoil water at the depth at which a tube well was finished and the flow of water in the tube was facilitated by the sandy layers of strata, without any formation of cavity. The author of the paper had, however, to be congratulated on his systematic treatment of the subject which had so far been so little talked about in this country.

Mr. A. S. Knox.

Mr. A. S. KNOX said that Mr. Trivedi was to be congratulated on his very interesting paper on experiments carried out on cavity type wells at Unao and Hathras. Mr. Knox had carried out experiments on similar lines in Bengal, Bihar and the United Provinces, but in no case had these proved satisfactory, and it was necessary to compare the strata in the borings referred to above with those in the experiments carried out by him. In every case tried by him the stratum was plain sand. It would be noted that the water bearing strata developed at Unao contained *kankar* and *bajri*. Efforts to develop the strata lower down in sand failed. At Hathras similarly each stratum developed contained *bajri* or *kankar* save the upper one and that was covered with sandy clay and *bajri*. It was significant that in both the wells *bajri* or *kankar* was present in the strata which developed satisfactorily. Mr. Trivedi's theory was that a cavity of shallow inverted mushroom shape was formed under the hard clay bed extending in the case of Unao to a diameter of approximately 200 feet. It was improbable that an unsupported roof of clay of a span of 200 feet would stand up. His opinion was definitely that it would not. He had had too many cases of a clay roof collapsing under such conditions. He had referred before to the fact that the sands were mixed with *kankar*. In the development of the wells he considered that the sand had been pumped out and the *kankar* had remained below forming a porous filter extending vertically and laterally to such an extent that at its boundaries the sand was under a stable regime. In other words the outer surface area of the *kankar* filter was such that the velocity of the water entering the filter was insufficient to move the sand and the regime was stable. Thus sand-free water was produced. It was probable that equally good results could be obtained at those places by lowering a coarse slotted pipe into the mixture of sand, *kankar* and *bajri* and blowing out until the sand was cleared out and the filter formed round the slotted pipe. That method was adopted in Burma in the Pegu sands which contained a large proportion of gravel. In fact, in Burma fine strainers were practically unknown. He had constructed "developed" wells in Burma in the manner indicated but had hastened and improved development by sinking auxiliary pipes round the main tube for feeding in gravel and extending the area of the filter. The process was that referred to by Mr. Trivedi at the end of his paper. He felt that he could not pass Mr. Trivedi's remarks about air lift pumping. For developing a well it could not be improved upon but for permanent pumping it was inefficient. The efficiency of an air lift pump was of the order of 20/25% and that of an efficient bore hole pump was from 60/75% while any depression

desired could be obtained with the latter. In fact, his firm installed a Cook's Deep Well Turbine pump lately at a depth of 150 feet in a tube well. He did not follow the author's formula. It did not appear correct to assume that the lateral velocity was equal to the vertical velocity in the pipe. According to the author, the sand surface from the foot of the pipe depended on the diameter of the pipe, irrespective of the velocity. If the shape of the cavern was as suggested by the author and the surface consisted of sand, the depth would increase up to the point at which the lateral velocity of the water was insufficient to disturb the sand. At Unao it worked out at about 8 feet per second at the foot of the pipe. In conclusion he again thanked Mr. Trivedi for his most interesting paper and suggested as a line for further experimental work the testing of the theory that yields of tube wells were directly proportional to the infiltration head. That was correct up to a point but how far it was not yet known.

Mr. W. E. Lane remaked that he could not add much to the comments made by Mr. A. S. Knox except to confirm the danger of a collapse of the clay roof as borne out by their own experience, that is to say, Messrs. Scott and Saxby's experience in the construction of gravel developed tube wells.

Col. F. C. Temple remarked that the first statement in the paper was a challenge. The yield from an open well sunk in sand could be made very considerable, if the sand at the bottom of the well was kept in its place by an inverted graded filter. The pamphlet "Surface Wells in Sandy Strata" (Thacker, Spink & Co.), explained fully how that could be done. The first sentence of the second paragraph invited criticism because a bulletin on the subject, published by the Government of the United Provinces, some 50 years ago, gave much valuable information on the subject. The paper, it was true, carried the investigation a good deal further than the former, and was for that reason a valuable contribution to the knowledge of such wells. The reports of the chemical analysis were very incomplete. There was nothing to show that the hardness of the water, or the magnesium content was in any way suitable for a domestic supply. It was much to be recommended that further investigation be made on the lines indicated and the results tabulated even more fully.

Rai Sahib K. C. Banerji: observed that the principles underlying the yield of wells had been investigated both theoretically and practically by eminent engineers in other countries notably in Germany and America, and the general accuracy of the results

K. C. Banerjee.

of these investigations appeared to be fairly established; the differences in their observations or formulæ might be due to different character of the water-bearing strata in which the investigations had been carried. The author would have done well had he followed their line of investigation and gave similar data with regard to the wells at Unao or Hathras. The author did not seem to have made any sand analysis, so it was not possible to find out if the change of the character of the sand grains was responsible for the clearness of water said to have been obtained at end. It might be there was a pocket of fine sand, which when pumped out was replaced by coarser sand offering less resistance to the flow of water, and the critical velocity of the sand grains or the velocity at which they started blowing, was higher. This velocity unfortunately did not appear to have been measured at any stage of the experiment. The calculation given by the author in Page 36 was not to the point, he had merely found out the length of the shell of the tube, equal to the area of its cross section. The flow of ground water, amongst others, depended upon the character and porosity of the stratum, the depth of lowering the water level, the hydraulic gradient of the water table, etc. These had not been taken into account in the calculation. In Page 37 Mr. Trivedi stated that at the end of the test the water obtained was practically free from sand, but he had not given any reason for this clearness; his experiment was not complete, he did not investigate the cause of the stoppage of sand blowing. Moreover, his remark did not agree with appendix A from which it appeared that practically the same amount of sand was pumped out each day in the latter part of the experiment as in the former, the only difference being that the proportion of sand to water pumped was considerably less, i.e., nearly one-tenth of the former. He had not stated how the removal of sand from the bottom would affect the stability of the well. From experiences at other places, it was believed that the well could not have a very long life. The only thing in favour of it was that there was no heavy machinery on the top of the well. The liability to failure by fracture of the clay bed by excessive pumping and thereby continuously removing sand forming its support, was obvious. Lastly, the discharge curves given in Plates III and VI were misleading. The graphical representation of the variation of yield with the depression of water level was almost straight only for some distance from the bottom and then it took the form of curve, i.e., an yield of 62% or so could be obtained when the water lowered to about 40% of the depth of water in the well and with about 75% lowering of water an yield of 90% could perhaps be obtained. Of course it would depend on the density of the water bearing

:. C. Banerjee.

strata and the slope of the water-table and other factors. The experiment was neither complete nor conclusive. Neither the safe nor the permanent yield had been determined.

Mr. F. C. Griffin.

MR. F. C. GRIFFIN observed that the tube well construction described in the paper was very interesting. The idea of the cavity at the bottom of the tube,—only 3" deep but of considerable area,—was quite intriguing. Near the bottom of page 33 of the paper there was the statement that Hathras had a battery of five tube wells, but there was no indication as to how near these wells were to each other. Presumably wells of this type would have to be a considerable distance apart, as otherwise the wells in the centre of a group would get little or no water. One could not imagine, for instance, that it would be workable to have the wells so close together that the cavities joined up. In Lower Bengal there was rarely, if ever, the thick bed of stiff clay which was necessary to make that type of tube well successful. The strata were mostly alternate layers of "sandy clays" and "clayey sands," and some sort of strainer,—preferably shrouded,—appeared to be necessary. At the end of the paper the author mentioned further developments which he hoped to describe on some future occasion. He did not know whether the author referred to the gravel bed tube well. Information as to whether that was applicable under conditions where there was no thick bed of clay would be very useful. He would like to ask whether information could be given as to the geological formation, and as to the direction from which water entered the water-bearing strata which was yielding the supply. The overlying stratum was described on page 38 as 170 feet of very stiff clay, and presumably the water could not get down through that stratum. He should also be glad to know what the hardness of the water was,—(the column was left blank in appendix B)—and also whether the uptake pipe of the tube well shown in Plate II had to be as small as 3 inch in order to bring up the sand. The yield was given as 221 gallons per minute, and the velocity of the water at this rate would be about 12 feet per second, with a loss of head of some 35 feet per 100.

The Author.

THE AUTHOR, in reply, said that Mr. B. P. Surti had inquired if there was any river near the site where tube wells had been constructed at Hathras. The answer was in the negative. Mr. Surti had explained very fully how fresh water could be obtained in an area where soil contained saline matter, provided there was a river close by. That seemed quite likely, but the question was up to how far the beneficial effect of the river was effective. He

had carried out some boring work at Shahdara near Delhi. The Author.
The Jumna flowed only a few miles from it and there was a big canal close by, still no fresh water was struck at 225 ft. depth, to which the boring was carried down. In another case where the water was brackish, a boring was carried out just close to a running canal. The subsoil water and the water found up to a depth of about 160 ft. below ground level was sweet, but when the boring was carried down to 250 to 260 ft., the water again became brackish. That point and many other points required considerable research. The presumption of Mr. Surti, that the test result of the sample given in the appendix in the case of Hathras tube well was for the sample drawn at 273 ft. depth, was correct. The samples from other depths were however not analysed.

Regarding Mr. B. Saroup's comments the author agreed with him that the developing of that type of tube well did take time and meant expense. In the case of the Unao tube well, however, considering the number of experiments carried out and the 12″ diameter tube well, the cost of Rs. 5,600 compared favourably with any metal strainer tube well with the additional advantage that there was nothing to clog. The strainer described by Mr. Saroup was very interesting but the author had no experience of it. Considering its cheapness, it would be worthwhile for the people interested in tube wells to give it a trial.

Mr. Irani had commented on the calculations given, regarding the extent of cavity found in the case of the Unao tube well. The author had already mentioned in his paper on page 35 paragraph 3, that those calculations of the diameter of the cavity were only guesswork, as the actual condition underneath could not be known by a single experiment. What had, however, been established beyond doubt was that the depth of the cavity did not exceed a few inches at the most. In the third paragraph of page 35 he had mentioned another point of view in connexion with the yield of water from sand, and it required considerable research work to find out the condition, how sands yielded up their water at various depths underground. Mr. Irani had also expressed his doubt regarding the risk of the layer of hard clay overlying the sand falling in unless the layer was very thin. He did not agree with that view as cases had come to his notice where fairly thick beds of clay, from underneath which a good deal of sand had been pumped out, had not been able to support even heavy masonry steinings erected over them.

Mr. Hogben's query as to how to find the natural rate of pumping of a well was not very easy to answer, but the author's experience was that if a depression head in ordinary strainer tube wells of about 15 to 20 ft. was not exceeded in the usual working, there was no danger of ruining the well. It had also been his experience that if a tube well was kept idle for sometime, it deteriorated very appreciably. Mr. Hogben's remarks about strainers were very interesting and bore out the author's experience also, as he had found that in many places long lengths of expensive strainers could have been easily substituted by very small lengths of properly constructed strainers without any reduction in their yield.

Mr. Chakravarti had raised the point regarding the yield of the old tube well constructed in 1915. Records showed that the tube well was 180 ft. deep and had 75' of 7" strainer in it and on first test yielded something like 500 gallons per minute. But there was no record of the depression head put on it. It could not, however, have been more than 15 or 20 ft. as no air lift was used at that time. As the records were very old, the author could not vouch for the accuracy of the discharge. In any case even if it was considered that it was only 250 or 300 gallons per minute, the tube well appreciably deteriorated on account of its long disuse. There was a great difference between a tube well lying dormant for a year and one remaining unused for 10 years. Messrs. Scott and Saxby's explanation that a hard crust of carbonate formed on the strainers was quite correct and it was due to this that the pores of the strainers clogged up and the discharge gradually fell in time even if a tube well was kept running but if the tube well was kept dormant it deteriorated much faster. The author agreed with Mr. Chakravarti that in the case of a tube well with long lengths of strainers the formation of a cavity was not necessary. But in strainerless tube wells, there was no doubt that some sort of cavity was formed which supplied water to the tube well. Mr. Chakravarti's assumption that there was a permanent level of subsoil water at a depth at which the tube well was finished was not borne out by experience, as this varied with variations in the seasons.

Mr. Knox said that he had tried this type of well in the plain sandy strata and it had failed. This was borne out by the

The Author. author's experiments also as, until the end of the tube was drawn up to the bottom of the clay, there was constant trouble with sand blowing into the tube. The author had not suggested in his paper that a cavity having a diameter of 200 ft. approximately had been actually formed as he had no means at his disposal to test the truth of that assumption. The only thing that was established was that the depth of the cavity did not exceed a few inches. So he only made an arithmetical calculation to show that the amount of sand pumped out represented an area having a diameter of 200 ft. He had also said that it was a mere assumption and that he had suggested another possible solution which, however, required experiments to prove it. Mr. Knox's explanation, that the sand stratum that was yielding water contained some *kankar*, which might support the clay bed, might also be true. His assertion that equally good results could be obtained at those places by lowering the coarse slotted pipe into the mixture of sand and *bajri*, had also been borne out by facts, as 2 or 3 wells constructed at Hathras were of that type and it was that type of tube well, which the author had referred to at the end of the paper. The author agreed with Mr. Knox that air lift was rather inefficient but as it had many advantages and combined with a boosting plant its efficiency compared favourably with other types of plant, it was invariably used for tube well pumping for water supplies in the United Provinces. Mr. Knox had referred to the formula given in the paper. Certain assumption had been made and considering the very small area to which it was applied it seemed reasonable. Further it very well explained the small depths of cavity. The author agreed with Mr. Knox that the relation of the yield of tube well and infiltration head was worth investigating.

Mr. Lane's fear of the collapse of the clay roof was not imaginary, but such a collapse was quite imminent if a thick bed of clay was not available for this type of roofing.

Mr. Temple had referred to the method of increasing the yield of open wells sunk in sand by putting on inverted graded filter. Such wells had not been tried in the United Provinces and the author had no experience of them. The method offered a very good scope for experiment and should be taken up by well engineers where conditions were suitable. The author regretted that he had not seen the bulletin referred to by Mr. Temple. He also regretted that the figures for the hardness of the water were not available for these particular wells, but that information was available

The Author. for other tube wells, sunk in the vicinity afterwards as given below:—

(a) Unao Tube Well. No. 3.	Total hardness	...	18
	Temporary hardness	...	8
	Permanent hardness	...	10
(b) Hathras Tube Well. No. 4.	Total hardness	...	18
	Temporary hardness	...	13·5
	Permanent hardness	...	4·5

In reply to Rai Sahib K. C. Banerjee, the author said that he hoped that the Rai Sahib did not subscribe to the view that it was always safe to follow a beaten track and that there could be no new line of attack, by which a problem could be solved. Necessary sand analyses by means of sieves and by means of grading with water were carried out for each type of sand that was pumped out and these were not given as these were considered unnecessary for the purpose of the paper. The quantity of sand that had been pumped out had not made much difference to the strata from which the water was being taken and in both cases it was very fine sandy clay interspersed with a few pieces of *kankar* and *bajri*, that was being depended on for the supply. With regard to the Rai Sahib's remarks that the critical velocity was not found out and that no account was taken of the character and porosity of the stratum, Mr. Trivedi said that the depth of lowering the water level and the hydraulic gradient of the water tables had very little bearing on the subject, as he was not in a position to carry out this work as a research scholar, but that he took some observations in the course of construction of those tube wells, which he had co-ordinated for the information of the engineering profession. He had never said that the results of the experiments were either complete or conclusive. He believed that immense research work was necessary to find out the behaviour of the sand beneath, in yielding its water. The Unao tube well was being worked since 1927 and there had been no fracture or failure by clogging up to this time.

The author would like to inform Mr. Griffin that the type of tube well referred to would be risky where a thick bed of clay was not available and for the type of strata met with in Bengal, the

slotted pipe tube well shrouded with ballast would be quite useful. The Autho. The soft clay encountered at both these places was practically devoid of any water. At Hathras, the distance apart of these wells was about 400 ft. from each other and some of these wells had got slotted pipe strainers shrouded with gravel. As regards the hardness of water the figures were not available. In Plate (2) was given the permanent arrangement and it would be seen that the outside system of air lift was employed. The discharge from this well was limited to 150 gallons per minute in the permanent arrangement.

THE B. T. U. IN AN INDIAN PAPER MILL

BY

A. R. BEATTIE, Member.

GENERAL: That the B. T. U. occupies an important position in the Paper manufactory is readily determined by the costs of steam and power, in their relation to the total production costs per ton of paper. Incidentally it may be remarked here, that coal costs per ton of paper is the term adopted throughout this note. This is, in preference to the widely accepted term 'tons of coal per ton of paper,' as this latter has an almost negative value in terms of comparison, by reason of the great variation in class and price of fuel as between mills. The principal factors in the coal costs of an industrial concern are dependent upon whether the plant is a modern one and the degree of efficiency attained in making the utmost use of a power and heat balance. This is particularly applicable to a Paper Mill, where the process demands the use of large quantities of low pressure heating steam. If this steam is generated in the first instance as high pressure steam, a double purpose may be served, namely, the supply of both heat and power. That there is sufficient inducement to a close up study of the conditions obtaining, and the possibility of savings on combined power and heating, proceeds from the fact that it requires only 2 or 3 per cent more heat to raise steam to high pressure than for the low pressures generally used for heating and process work. To be exact, the total heat in steam at 200 lbs. pressure is only 2.7 per cent more than at 20 lbs. It follows that by raising steam to a high pressure, and passing it through an engine or turbine, power can be obtained at a much lower cost than is possible even in the most modern generating stations, where the B.T.U. performance is carefully recorded in all its stages in the search for the higher efficiencies and reduction of power generation costs. This will be more fully dealt with at a later stage in this note.

COAL: (a) *Selection, Grading and Analysis*:—As coal is a source of the B.T.U. it is deserving of careful consideration. There is perhaps no single item in the operation of an existing plant, or in the design of a new plant, that affords such an opportunity for effecting economy as the selection of fuel. There are many factors involved and each plant is really an individual problem. The solution of the problem is largely a matter of boiler tests. All coal samples for analysis should be selected and

quartered, as standard practice and in order to secure as representative results as possible. This is particularly important where coal supplies are drawn from various seams. A point to be carefully remembered is that the smaller grades of coal (unless they are well washed) have naturally a lower calorific value owing to the higher percentage of foreign matter they contain. It is also important to remember that in boiler testing it is difficult to obtain representative average samples of the fuels used if the fuels vary much in size. If the samples are not very carefully taken the calorific value shown might be too high and this would reduce the apparent efficiency of the boiler-plant and increase the unaccounted for loss. At the best, coal sampling is a very tricky business.

(b) HEAT VALUE.

The following table shows the theoretical heat value, deduced from an average proximate analysis of various coals used on a series of boiler tests preparatory to certain grades being selected for supply in a yearly contract basis.

Test No.	PROXIMATE ANALYSIS CALORIMETER.				HEAT VALUE B.T.U. PER LB
	Moisture per cent	Ash.	Volatile Matter.	Fixed Carbon.	As Received on site.
1	3.38	10.07	33.98	52.57	12704
2	2.50	10.72	35.21	51.57	12693
3	5.96	15.70	30.69	47.65	10618
4	0.77	19.67	22.48	57.08	12268
5	0.61	16.12	20.35	62.92	12690
6	6.95	16.61	32.13	44.31	11162
7	1.17	19.24	22.99	56.60	12650
8	0.70	31.79	18.13	49.38	10516
9	0.93	21.91	20.37	56.79	12152
10	3.87	18.19	32.03	45.91	11682
11	0.95	30.71	18.28	50.06	10621
12	8.83	15.40	30.15	45.62	11639
13	1.64	18.43	23.83	50.10	12536
14	10.23	12.26	31.20	46.31	11458
15	5.56	14.82	27.84	51.78	12052
16	4.46	24.39	26.54	41.61	10716
17	7.51	15.08	31.27	46.11	11223
18	4.40	14.44	28.09	53.07	12517
19	1.53	22.20	16.32	59.95	11804
20	0.85	17.42	19.70	62.03	12867
Average Results	3.64	18.25	26.07	52.02	11837

(c) *Deductions* :—

The results of these tests show a variation in heat value of from 10500 B.T.U. to 12800 B.T.U. with an ash by analysis variation of 10 to 30 per cent. The average results approximate fairly closely to the analysis of the grade of fuel finally adopted and which for all practical purposes may be considered as having a heat value of 11500 B.T.U. per lb. of fuel.

BOILER TESTS.

The following is an example of the boiler tests referred to in determining the most suitable grade of fuel to meet conditions.

BOILERS: 3 B & W W.I.F. type, heating surface	5397 sq. ft. each
SUPERHEATER B & W (Integral) heating surface	980 ,, ,,
STOKERS B & W Chain Grates, Total surface	114 ,, ,,
ECONOMISERS Green's Vertical heating surface	2000 ,, ,,

OBSERVATIONS

Duration of test	6 hours
Conditions of test	Maximum Load

FUEL.

Name and class	Saltore Screened Dust
Total as fired in test (wet) lb.	49104 lb.
Total ,, ,, ,, ,, (dry) lb.	47852 lb.
Consumed per hour	6184 lb.
Thickness of fire	3·75 inches
Ash by analysis	10·72 %
Unburnt Carbon in ash (Analysis)	2·30 %

ANALYSIS BY WEIGHT OF FUEL AS FIRED.

Carbon	71·40 %
Hydrogen	5·65 %
Nitrogen	1·89 %
Oxygen	7·44 %
Sulphur	0·35 %
Ash	10·72 %
Moisture	2·55 %
	100·00 %

Net or Lower Calorific Value of Fuel as fired. 12693 B.T.U.

FLUE GASES.

	By Volume	By Weight.
CO_2	11·00 %	16·08 %
CO	nil	nil
O_2	9·00 %	9·52 %
N_2	80·00 %	74·40 %
	100·00 %	100·00%

Flue gas temperature before economiser	511 Deg. Fah.
Flue ,, ,, after ,,	366 ,, ,,
Boiler House ,,	95 ,, ,,
Draught at entering economiser	0·625 ins. W.G.
Draught at near Chimney base	0·850 ,, ,,

STEAM

Average pressure	195 lb in. Gauge
Saturated temperature	386 Deg. Fah.
Total ,,	586 ,, ,,
Degree of superheat	200 ,, ,,

WATER

Temperature entering economiser	159 Deg. Fah.
Temperature leaving ,,	259 ,, ,,
Total evaporated actual	404730 lb.
Per hour actual	67455 lb.
Cost of evaporating 1000 galls. actual	Rs. 4 2 3
Cost of ,, 1000 ,, from and at 212 Deg. Fah.	Rs. 3 5 9
Lb. of water evaporated per anna of cost	151 lb.

DEDUCTIONS.

Total evaporated per hour from and at 212 Deg. Fah.	82800 lb.
Per lb. (Wet) coal actual	8·24 lb.
Per lb. (Wet) ,, from and at 212 Deg.Fah.	10·11 lb.
Per sq. ft. H.S. ,, ,, ,, ,, ,,	4.33 lb.
Factor of evaporation including superheat	1·23
Theoretical evaporation as conditions	10.61 lb.
Mean specific heat of products of combustion	0·24 B.T.U/lb./Deg. Fah.
Air used per lb. of fuel as fired	14.75 lb.
Air theoretically required per lb. of fuel as fired	9·26 lb.

Ratio of air used to theoretical air	1·59	
Wt. (theor.) of products of combustion as fired	10.11	lb.
Wt. (Actual) off gases per lb. of fuel as fired	15.60	lb.

HEAT ACCOUNT

	B.T.U.	
Heat transferred to boiler and superheater	9000	71·00 %
Heat ,, ,, economiser	825	6·50 %
Thermal Effy., boiler, superheater and economiser combined	9825	77.50 %
Heat lost to products of combustion	1018	8.00 %
Heat ,, ,, excess air	552	4.32 %
Heat ,, ,, steam from combustion	673	5.30 %
Heat ,, ,, unburnt carbon in ashes	248	1.93 %
Balance of heat account, errors of observation unmeasured losses such as due to radiation escape of unburnt hydro carbons, superheating moisture in air etc.	377	2.95 %
Total heat value per lb. fuel as fired	12693	100.00 %

BOILER TEST RESULTS.

The results of tests in general show an overall boiler efficiency, varying from 52% to 68% on the Lancashire boilers and 70% to 77% on the B. & W., W.I.F. type, water tube boilers with a cost variation of sixty to eighty-four pence, per 1000 gallons, actual, water evaporated. The normal efficiency with the boilers operating under every day load conditions, and when using coal with a calorific value of 11,000 B.T.U. is approximately 64 per cent on the Lancashire boiler, and 72 per cent on the water tube boiler respectively. Steam generating costs are very definitely in favour of the lower grade fuels. It may be stated at once that the figure of 64 per cent efficiency leaves considerable margin for improvement, even on Lancashire boilers which have been in commission over a very long period. The figure of 72 per cent efficiency on the water tube boilers, when compared with the 85 per cent of a modern boiler unit with all its instrument aids, is apt to lead to a feeling of depression, but on the other hand—considering the limitations imposed by the class of labour employed the attainment of the lower efficiency may be the greater personnel achievement, and as such, should act as an incentive to establishing a still closer contact with the elusive B. T. U.

BOILER INSTRUMENTS.

Economics in the production of steam are invariably a direct result of accurate and detailed knowledge of what is occurring in the boiler house. The installation of metering equipment at the steam boiler plant can therefore be recommended with every confidence, as its intelligent use will ensure a speedy return on its capital outlay, and what is more important a permanent record of plant performance and efficiencies. The mention of meters usually raises a vexed question with those concerned with finance and for this state of affairs the boiler maker is largely to blame. The maker's equipment of a modern boiler unit, even to-day, seems to be largely determined by the bare necessities of the boiler regulations, and metering equipment if mentioned is quoted as 'extras.' Anything in the nature of 'extras' is immediately suspect, whereas if the boiler specification covered complete metering equipment, as an integral part of the unit, it would be accepted in the ordinary course. On the plant under review a permanent record is obtained of operation under every day conditions of load and which after all is a true measure of plant efficiencies. Moreover, detailed and accurate recording leads to accurate costs and closer contact with the source of losses.

PIPE SYSTEMS. It will perhaps be of some interest if we deal with the layout of steam and exhaust piping. Steam mains should have the treatment they deserve, by reason of their importance in plant economics. For steam mains it is advisable to draw up a diagram shewing the relation between pressure drop, steam—consumption, radiation losses, etc. From consideration of this it is possible to obtain the exact size of the pipe which will be most economical for the duty considered.

RADIATION LOSSES. Steam pipes, feed-water pipes, boiler steam drums, receivers, separators and the like should be covered with heat insulating material to reduce heat losses to a minimum. Data available conclusively proves that the heat loss from bare pipes conducting heated fluids is so great that any good grade of pipe covering will pay for itself in a comparatively short time.

The following "Unlagged Surface Heat Loss Table" has been compiled from actual tests carried out by the N.P.L. Teddington.

Heat loss from uncovered surface and through 1½", 2", and 2½" 85% Magnesia Plastic Composition on a six inch bore steam pipe. Air temperature at 70 degs. Fah.

B. Th. Us. ESCAPING PER HOUR PER SQ. FT. OF HEATING SURFACE.

Steam Temperature in degrees Fahrenheit.	Uncovered Pipes.	1½" thickness of Magnesia	2" thickness of Magnesia.	2½" Magnesia.
100	58	9.6	7.32	6.28
200	297	41.75	31.70	28.30
300	648	74.60	56.90	48.75
400	1146	109.20	83.50	71.40
500	1815	147.20	113.00	97.50
600	2680	187.00	142.00	120.50
700	3760	229.00	175.50	148.00
800	5180	275.00	209.00	178.00
900	6850	331.00	248.30	212.00
1000	8930	380.00	292.00	255.00

Dealing with insulation of steam installations, the following example illustrates the monetary saving which it is claimed can be effected by a first class insulation, as against no covering.

Example :—A tri drum water-tube boiler operating under the following conditions :—

Heating surface	6377 sq. ft.
Steam pressure	200 lbs. gauge.
Superheated steam temp.	638 degs. F.
Average efficiency	72 per cent.
Coal per hour	3030 lbs.
Grade of coal	Unscreened Slack
Price of coal per ton	Rs. 6 0 0
Insulation -	
Drums, Boiler pipes, and Valves.	2½" 85% Magnesia and 1" hard-setting composition
Superheated and other pipes	1½" to 2½" 85% Magnesia and ½" hard-setting Composition.
Insulated area	1085 Sq. ft.
Heat leakage uncovered surface	3,363,500 B. Th. Us. hr.
Heat leakage covered surface	141,050 ,, ,, ,, ,,
Heat saved per hour	3,222,450 ,, ,, ,, ,,
Equivalent coal tons—310 days	1482
Saving in cost of fuel per annum	Rs. 8892/-.

Here the initial applied cost of the insulation would be approximately Rs. 1350/-, *an outlay which is recovered in less than two months operation.* Perhaps the importance of heat losses may be best understood from the fact that each square foot of bare surface at a temperature of say 400 degs. F. represents 1185 lbs. of coal per annum. It is obvious therefore that heat losses can be a serious handicap, where, as in a paper manufactory, the steam using equipment is very extensive.

POWER AND HEAT BALANCE. It is doubtful if any plant can be found having such a relation of power and steam loads as to make possible *a complete balance*, with all power obtained as a by product of the reduction of steam pressure to that required in manufacturing process. The problem is increasingly difficult, as with the plant under review, where existing higher limit steam pressures do not permit of the turbine being bled at an extraction steam pressure suitable to a complete range of process requirements. The steam extraction point in this instance being suitable for process on the lower pressures only. It is necessary in this case to generate steam in low pressure boilers and which is not conducive to higher efficiency. The existing boilers were designed for a working pressure of 200 lbs. gauge and a superheat of 150 degs. F. or a total steam temperature of 538 degs. F. Permission to increase the steam pressure was refused. After full consideration it was decided that the superheat be increased to 250 degs. F. representing a total temperature of 638 degs. F. A 2500 kw. B.T.H. multistage extraction type turbo alternator was installed, with a rating as follows:—

Normal rating	2500 kw.
Steam press at stop valve	190 lbs. gauge
Steam superheat ,, ,,	250 degs. F.
Vacuum (Bar. 30")	27.5 ins.
Heating steam press 30 lbs. G.	All loads
Heating steam per hour max.	35000 lbs. hr.
K. V. A.	3125
P. F.	80%
K. W.	2500
Voltage	500
R. P. M.	3000
Frequency	50
Phases	3

The undermentioned data has been deduced from tests on site and with certain assumptions.

Account.	Stage 1	Stage 2	Stage 3
Load	1400 kW.	1880 kW.	2030 kW.
Rating of Machine	1500 kW.	2500 kW.	2500 kW.
Steam pressure	160 lbs.	200 lbs.	200 lbs.
Degree of superheat	150 degs.F.	250 degs.F.	250 degs.F.
Vacuum	27.5 ins.	27.5 ins.	27.5 ins.
Process steam press direct (1)	80 lbs.	80 lbs.	80 lbs.
Process steam press extract (2)		30 lbs.	30 lbs.
Process steam demand /hr. (1)	36900 lbs.	23300 lbs.	12500 lbs.
Process steam demand /hr. (2)	......	19280 lbs.	21500 lbs.
Power steam demand /hr. condenser	25200 lbs.	20200 lbs. *	19100 lbs.
Load Factor 340 days annum	8160 hrs.	8160 hrs.	8160 hrs.
Coal price ton delivered	Rs. 6/-	Rs. 6/-	Rs. 6/-
Calorific value as fired	11000 B.T.U.	11000 B.T.U.	11000 B.T.U.
Temperature at entering economiser	122 degs.F.	162 degs.F.	162 degs.F.
Lbs. evaporation lb. coal	5.92 lbs.	6.58 lbs.	6.85 lbs.
Boiler efficiency combined	64 per cent	72 per cent	75 per cent.
Coal consumption— 1000 B.T.U.	0.142 lbs.	0.126 lbs.	0.121 lbs.
Cost of Heat— 1000 B.T.U.	0.006 anna	0.0054 anna	0.0052 anna
Coal consumption— Process	22710 tons	23574 tons	18081 tons.
Coal consumption— Power	15507 tons	11183 tons	10158 tons
Coal cost— Process—	Rs. 1,36,260	Rs. 1,41,444	Rs. 1,08,486
Coal cost— Power	Rs. 93,042	Rs. 67,098	Rs. 60,948
Total coal consumption	38217 tons	34757 tons	28239 tons
Total coal cost	Rs. 2,29,302	Rs. 2,08,542	Rs. 1,69,434
Total power produced kWh	11424000	15340800	16564800
Steam consumption kWh			
Heat consumption kWh	21420 B.T.U.	12931	
Coal consumption kWh	3.02 lbs.	1.63 lbs.	
Coal cost kWh	0.127 anna	0.0698 anna	0.0589 anna
Turbine effy. ratio	57.64%	*67%	*67%
Turbine thermal effy.	15.76%	25.36%	28.85%
Overall thermal effy.	10.28%	19.04%	22.65%

*(Makers effy.)

DEDUCTIONS. The results obtained on Stage 1, and Stage 2, represent a period in plant renovation, and the result aimed at in Stage 3, marks an immediate improvement in plant efficiencies.

It will be noted that the overall thermal efficiency for power, at 28.85 per cent, compares very favourably with even the best super stations to-day. As the turbine is not yet fully loaded the efficiency will naturally increase when the load is increased. As it is, however, certain subsidiary plant is even now operating on a back pressure basis at an OVERALL THERMAL EFFICIENCY of 53.86 PER CENT. These results demonstrate in no uncertain fashion the economic advantages of a combined power-and-process plant in an industrial undertaking.

PROCESS. Paper is made from the fibres of plants which are contained in such Raw Materials as Rags, Wood, Grass, Straw,

Bamboo and old Papers. These may pass through many processes in the paper mill before the fibres are ready for use, but the actual operation of making paper is simple. (The papermaker naturally holds other views on this subject.)

PROCESS STEAM USES :—Ordinarily the heat required by process is known from past records or can be closely estimated. A steam flow diagram is of some considerable assistance in locating and estimating heat quantities in the various processes common to the manufacture of paper. In heating schemes the important point to bear in mind is that the energy dissipated in the process of heating is derived from the *latent* heat of the steam and not from the *sensible* heat. When this principle is grasped it will be seen that the back pressure against which the turbine is required to work should be as little as possible above the pressure which corresponds to the temperature required at the point where heating takes place. The use of exhaust steam provides the mill with power costing only the price of heat units taken out of the turbine, between the limits of the initial steam pressure and the terminal pressure obtaining at the extraction point. Perhaps just how simple it is in certain circumstances to obtain this advantage is revealed in the following test carried out by the writer, over a period of ten months on a section of plant in the paper mill. The papermaking machines are driven by simple horizontal type single cylinder, slide valve engines, with a cylinder diameter of 15 inches 2 ft. stroke, and normally running at 95 r.p.m. It was found that when using turbine exhaust steam at 30 lbs. gauge pressure an engine of this type operated very successfully when exhausting against a back pressure of 15 lbs. absolute to the drying cylinders of the papermaking machine. The whole of the engine exhaust steam was used for paper drying and the resultant condensate returned to the steam boilers at a temperature of 192°F. It is of some considerable interest to note *that, with the turbine operating at 72 per cent of normal rating, the coal cost per k.w.h. in terms of by-product power—as conditions of test—is as low as 0.0074 annas.* With the turbine operating straight condensing the coal cost per k.w.h. is 0.085 annas. The contrast is a striking one indeed.

GRASS BOILING :—

The following results are deduced from theoretical data applicable to the digestion of grass in actual practice. As for example :—

Steam Calculations relating to digestion of Grass by Overhead method in Sinclair's Digesters—45 Cwt.

Capacity of digester 572 Cu. ft.	45 Cwt.
Surface area 378 Sq. ft.	Weight 4 tons.

Volume of Liquor used for cooking taken at 2000 gallons containing $17\frac{1}{2}$ lbs. NaOh per cwt. of grass boiled.

Water Equivalents and Temperatures.		Lbs.	Temp.
Charge 45 Cwt. × 112	5040 lbs. × .6	3024	90° F.
Liquor 2000 Gallons × 10 × .96		19200	100° ,,
Digester 4 tons × 2240 × .117		1048	90° ,,
Total water equivalent and mean temp.	=	23272	98° ,,

Radiation Losses. Calculated by means of curves—vide Nat. Phy. Lab. and L. B. Mc Millan.

Steam Supply.

Low Pressure at 30 lbs. gauge Temp. 274°F. Heat Value 1175

High Pressure at 80 lbs. gauge Temp. 324°F. Heat Value 1191

(1) Heating up to 30 lbs. gauge = 274°F.

$$\text{Steam :—} \quad \frac{23272 \times (274 - 98)}{1175 - 274} = 4546 \text{ lbs.}$$

(2) Radiation during heating to 30 lbs. gauge
Mean temp. 215°F. Air temp. 90°F
Temp. difference 125° F. k = 3. Area = 378 sq. ft.

$$\text{Steam :—} \quad \frac{125 \times 3 \times 378}{1175} = 121 \text{ lbs.}$$

$$\text{Time 2 hours} \quad 121 \times 2 = 242 \text{ lbs.}$$

(3) Heating up to 80 lbs. gauge = 324°F.

$$\text{Steam :—} \quad \frac{(23272 + 4546 + 242)\ (324 - 274)}{1191 - 324}$$

$$= \frac{28060 \times 50}{867} = 1618 \text{ lbs.}$$

(4) Radiation during heating to 80 lbs. gauge.
Mean temp. 246°F. Air temp. 90°F.
Temp. difference 156°F. k = 3. Area 378 sq. ft.

$$\text{Steam :—} \quad \frac{156 \times 3 \times 378}{1191} = 148 \text{ lbs.}$$

$$\text{Time } \tfrac{1}{2} \text{ hour} \quad 117 \times \tfrac{1}{2} = 74 \text{ lbs.}$$

(5) Radiation during digestion at 80 lbs. gauge
Mean temp. 324°F. Air temp. 90°F.

Temp. difference 234°F. k = 3. Area 378 sq. ft.

Steam :— $\dfrac{234 \times 3 \times 378}{1191}$ 223 lbs.

Time 4 hours 223 × 4 = 892 lbs.

Table for Overhead Digestion of 45 Cwts. Grass in Sinclair Digester.

		Steam lbs.	Time
(1)	Heating to 30 lbs. pressure	4546	2 hours
(2)	Radiation during (1)	242	
(3)	Heating to 80 lbs. pressure	1618	½ hour
(4)	Radiation during (3)	74	
(5)	Digestion at 80 lbs. pressure	892	4 hours
		7372	6½ hours
	L. P. Steam	4788 or	64·94%
	H. P. Steam	2584	35·06%
		7372	100.00%
	Steam per hour	1134	
	,, ,, ton	3276	
	,, ,, cwt.	164	
Steam per 1 lb. Grass		1.46 lbs.	(Digesters Unlagged).

As a comparison it may be stated that on a series of actual tests carried out by the writer the results were as follows :—

(a) By the *indirect* method of digestion the steam consumption per lb. of grass was 1.52 lbs. by actual weighment of condensate plus equivalent steam for electrically driven auxiliaries.

(b) By the *Overhead* method of digestion the steam consumption per lb. or grass was 2.26 lbs. by actual weight of digester contents plus steam for loading, measured by a special orifice inserted in the branch steam main to the digester. In each case the digesters were unlagged and in test (b) the caustic liquor was not preheated.

In no section of the pulp or papermill is the application of steam carried out in such a drastic manner as at the digesters. Excessive steam peak loads are the rule, rather than the exception and although the *mean average* steam consumption figure, in

lbs. per hour, may appear an excellent one the equivalent coal consumption at the boiler furnace suffers much by comparison.

SODA RECOVERY :—The waste soda lyes from grass boiling, by what is known as the soda process, are evaporated to dryness, and the residue calcined in order to recover the soda for re-use. Triple and quadruple effect multiple evaporators are employed to concentrate the weak soda lyes to a density of from 50 deg. to 60 deg. Twaddel, the final evaporation and calcination of the residual mass being carried out in a rotary roaster.

The processes which occur in a multiple effect evaporator, both in regard to the efficiency and the consumption of steam, are somewhat more complicated than in a single evaporator.

The process of evaporation is as follows :—

The steam from the liquor in the first vessel produced by the action of the hot steam which is supplied externally, passes into the heating chamber of the second vessel, there in turn produces vapour from the liquid, and is condensed, escaping at the temperature prevailing in the lower part of the liquid in that second vessel. The weight of liquid which has lost weight of water by evaporation in the first vessel, and which consequently now weighs less than by that amount passes at the mean temperature of the first vessel, into the second vessel, in which the mean temperature is much lower. Thus, in cooling from (tm1) to (tm2) it must form steam.

In the second vessel steam is thus evolved both by reason of the heat of the hot liquid itself and also because of the steam coming from the first vessel. In the third vessel steam is produced both by the heat of the entering liquor and also by reason of the heat of the steam which is the total steam produced in the second vessel. In the fourth vessel a similar action is produced so that in addition to the repeated action of the hot steam produced there is also the repeated action of the steam produced by the decrease in temperature of the liquor.

As the consumption of heating steam in the first vessel is the only steam used from an external source we may proceed to ascertain this by the following formula :—

$$S = \frac{W\ (ti - tf) + x\ (Ti - ti)}{T - ti}$$

Where W = The quantity of liquor introduced.

ti = The temperature of the steam in the steam space of the vessel.

tf = The temperature of the liquor entering the vessel.

X = The quantity of water to be evaporated from the liquor in the first vessel.

Ti = Total heat in the steam evolved within the first vessel.

T = Total heat in the steam as supplied.

By substitution of figures obtained on actual tests at 3,000 gallons of liquor per hour with a concentration of from 4° Tw. to 60° Tw. or an evaporation of 2,800 gallons of water, we have :—

$$\frac{30,000\ (240 - 181) + 6,480\ (1,160 - 240)}{1170 - 240} = 8,220 \text{ lbs. steam per hour.}$$

$$\text{and } \frac{28,000}{8.220} = 3\cdot406 \text{ lbs. water per 1 lb. steam.}$$

The figure of 3·406 lbs. water per 1 lb. of steam is in accordance with actual practice when operating a quadruple effect evaporator under reasonable conditions of efficiency.

In the next place it is desirable to find the evaporative efficiency of each vessel and the percentage of solid matter in each, for liquors varying in strength both before and after evaporation.

EXAMPLE :—3,000 gallons of a liquor, containing 4 per cent of solid matter, are evaporated to a strength of 60 per cent, in a quadruple effect evaporator.

In order to evaporate 3,000 gallons of liquor from 4 per cent to 60 per cent strength

$3,000\ (1 - \frac{4}{60}) = 2,800$ gallons, water must be evaporated.

Vessel	I evaporates	28000	× 0.2161	=	6050.800	lbs.
,,	II ,,	6050.8	× 1.123	=	6795.048	,,
,,	III ,,	6050.8	× 1.187	=	7182.3996	,,
,,	IV ,,	6050.8	× 1.316	=	7962.6528	,,
					27990.9004	,,

Thus the first vessel contains

4% of solids in 30,000 − 6050.80 = 23949.20 lbs. of solution, *i.e.*, in the solution there is

$$\frac{4 \times 30,000}{23949.20} = 5.01 \text{ per cent of solids.}$$

The second vessel contains

4% of solids in 23949.20 − 6795.04 = 17154.16 lbs. of solution, *i.e.*, in the solution there is

$$\frac{4 \times 30{,}000}{17154.16} = 6.99 \text{ per cent of solids.}$$

The third vessel contains

4% of solids in 17154.16 − 7182.39 = 9971.77 lbs. of solution, *i.e.*, in the solution there is

$$\frac{4 \times 30{,}000}{9971.77} = 12.03 \text{ per cent of solids.}$$

The fourth vessel contains

4% of solids in 9971.77 − 7962.65 = 2009.12 lbs. of solution, *i.e.*, in the solution there is

$$\frac{4 \times 30{,}000}{2{,}000} = 60 \text{ per cent of solids.}$$

The subject of multiple effect evaporators has been dealt with perhaps rather fully, but it is felt that this is deserved, as considerable scope exists in this section for the efficient utilisation of low pressure heating steam on a back pressure basis.

MACHINE DRYING OF PAPER.

The drying effect in a paper machine is produced by the transfer of heat through the shell off the cylindrical dryers from the heat given off by the steam within. This heat is transferred to the sheet which is held in contact with the external surface of the cylinders driving out the moisture in the sheet. Water and air must be eliminated from the cylinders if maximum efficiency and drying capacity are to be secured, for the cylinder is naturally most effective when in active circulation. The elimination of water and air from paper machine cylinders is, and always has been, a constant problem which paper mills have to face. The problem is further complicated by the fact that steam must be used economically.

It has been found, by numerous tests, that about three pounds of steam are required to dry one pound of paper in actual practice. The theoretical quantity may be determined by the following formulas:—

$$S = \frac{X\ (T - ti) + ws\ (tf - ti)}{Ti - tf}$$

Where S = Lbs. of steam required.

X = Weight of water in lbs. which has to be evaporated for each ton of air dry paper made.

W = Weight of air-dry cellulose (= 2,240 lbs).

s = Specific heat of air-dry cellulose.

ti = The initial temperature of pulp and water running on the wire.

tf = The final or maximum temperature to which the pulp is heated on the drying cylinders.

T = The total heat units contained in 1 lb. of steam at 212°F. under atmospheric pressure.

Ti = The total heat units contained in 1 lb. of steam at the pressure prevailing within the drying cylinders.

X is ascertained by estimating the water in the pulp after passing the press rolls, and again after having passed over the drying cylinders.

This may be calculated as follows :—

$$W = \frac{M1 - M}{100 - M1} \quad \text{where}$$

W Lbs. water evaporated per lb. dried paper.

M1 Percentage of moisture in sheet entering the dryers.

M Percentage of moisture in dried sheet

As for example paper entering 30 per cent dry equals 70 per cent moisture. Paper leaving equals 6 per cent moisture. By substitution we have :—

$$\frac{70 - 6}{100 - 70} = 2.14 \text{ lbs. water evaporated per lb. paper.}$$

By substitution of figures obtained on actual tests we have :-

$$\frac{5{,}226\ (1{,}150 - 96) + 2{,}240 \times 0.55\ (200 - 96)}{1{,}160 - 200} = 5{,}871 \text{ lbs.}$$

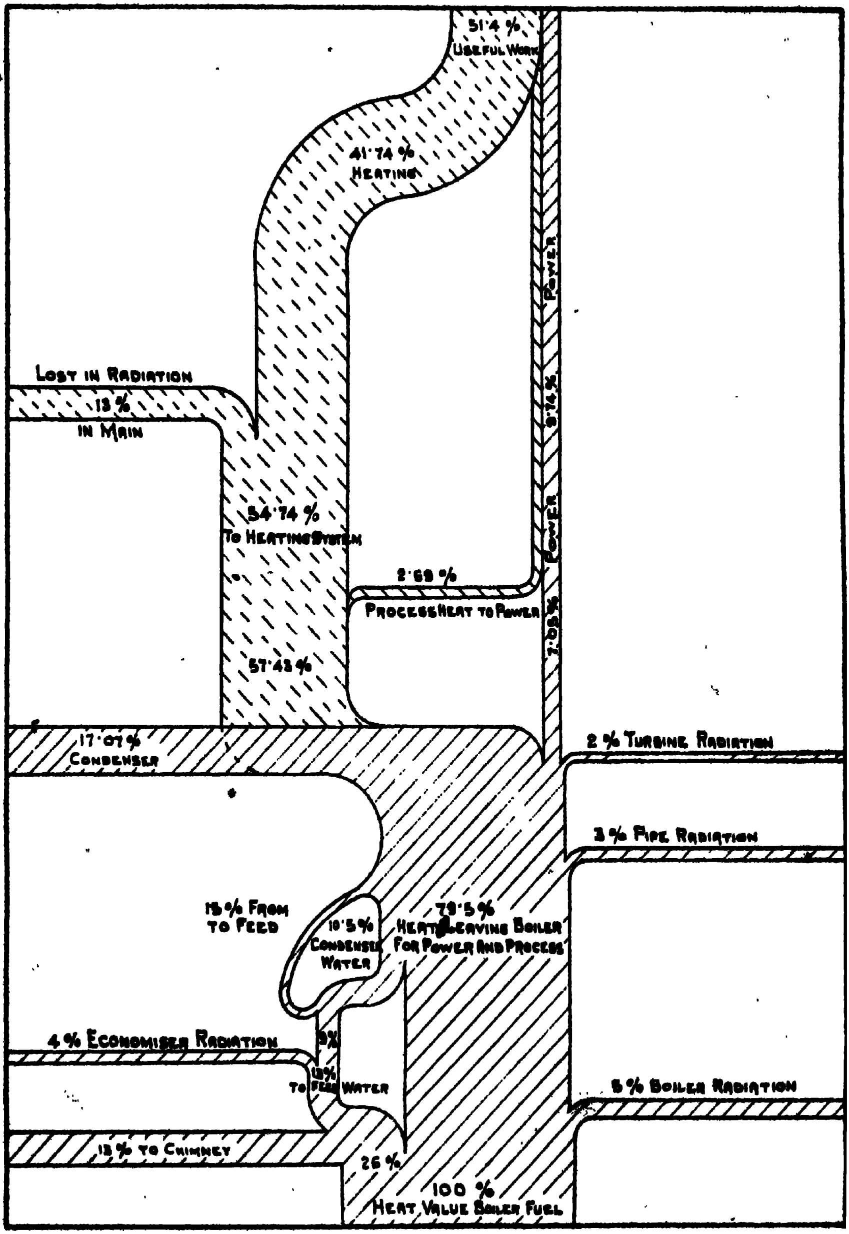
The actual steam consumption per lb. of paper obtained on an actual test as conditions above was 3.134 lbs. as compared with the 2.621 lbs. by calculation or an efficiency of 83 per cent which is a reasonable figure for slow running machines. The balance of 17 per cent represents loss of heat by radiation, moisture in steam, etc.

SUMMARY:—Industrial power plant engineering offers a splendid opportunity for an intensive study of operating conditions and their application towards the most economical range for power and heat development. Each individual plant is a problem in itself the solution of which calls for a careful survey and analysis of the various factors concerned. The writer has made copious notes of methods applicable to the particular plant under review and the results obtained. These do not come within the province of this article, but will be dealt with on another occasion. In any well laid-out plant it is essential to have, as far as possible, a balance between expenditure and capitalised economies as second only in importance to realiability of operation. With a plant in operation 24 hours daily, maintenance liabilities are greatly increased but in such cases an excellent load factor is usually a sufficient inducement to a high efficiency standard being, at least attempted. In every instance a factor of primary importance is EFFICIENT CONTROL OF THE B. T. U.

APPENDIX.

Plate No. 1.

Diagram showing heat losses in steam power plant of a Paper Mill.



BEATTIE ON THE B.T.U. IN AN INDIAN PAPER MILL.

Plate No. 2.

Diagram showing heat balance for separate heating and power boilers in a Paper Mill.

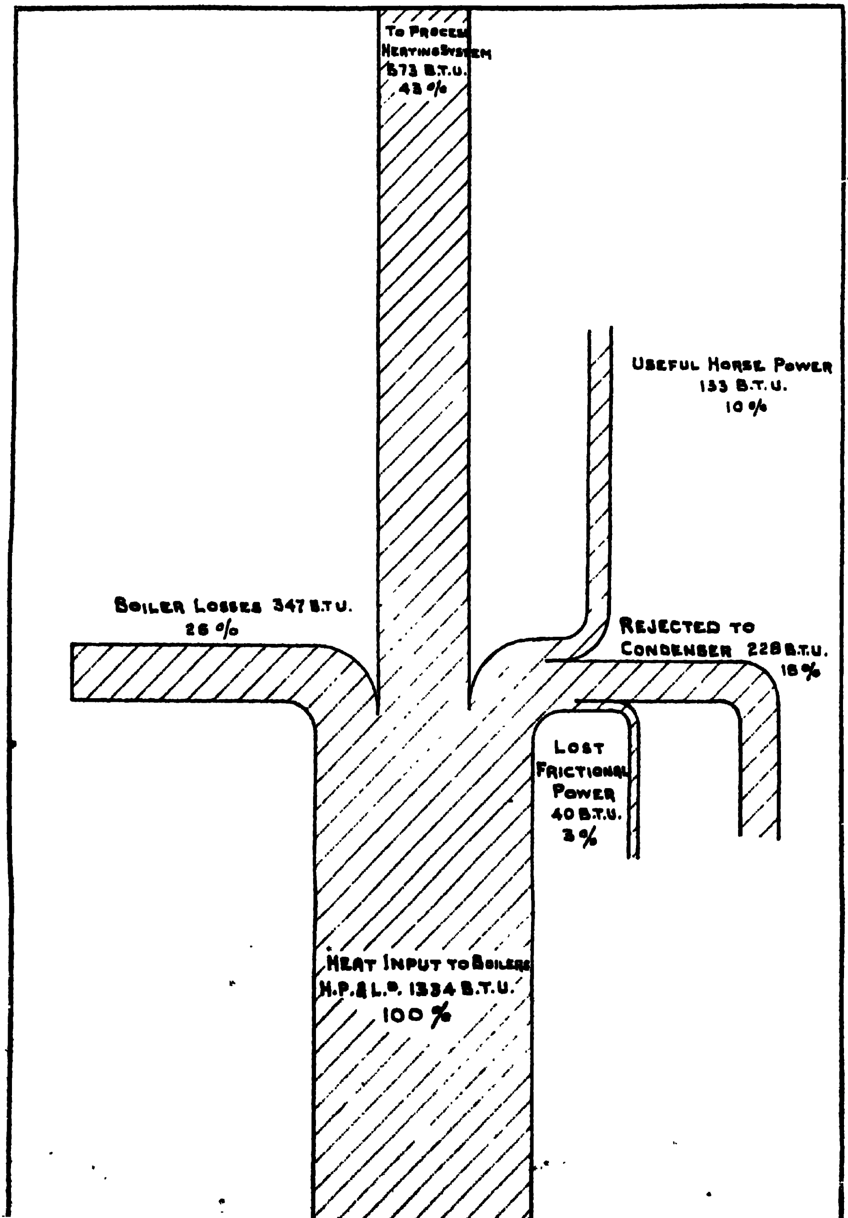


Plate No. 3.

Diagram showing combined power and heating costs in a Paper Mill.

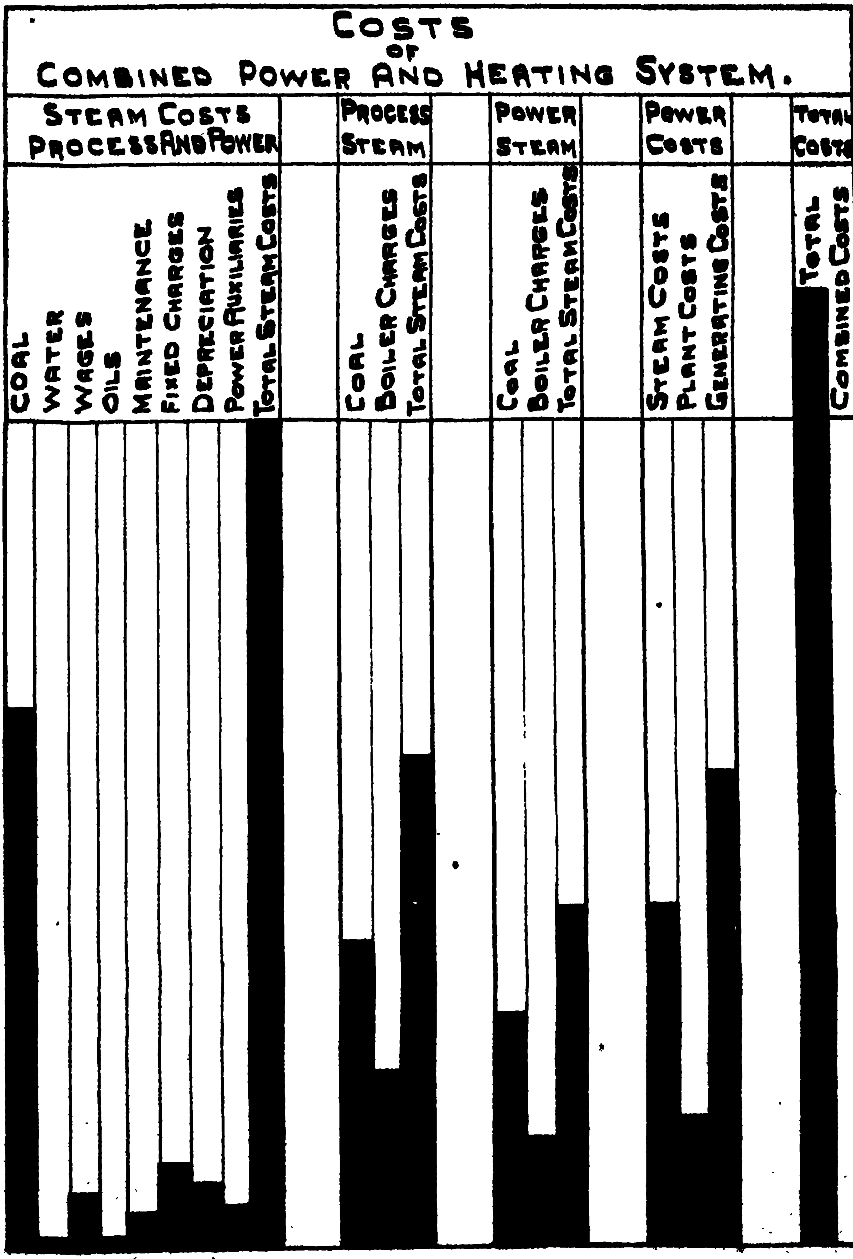


Plate No. 4.

Diagram showing process steam consumption in the digestion of raw fibres in a Paper Mill

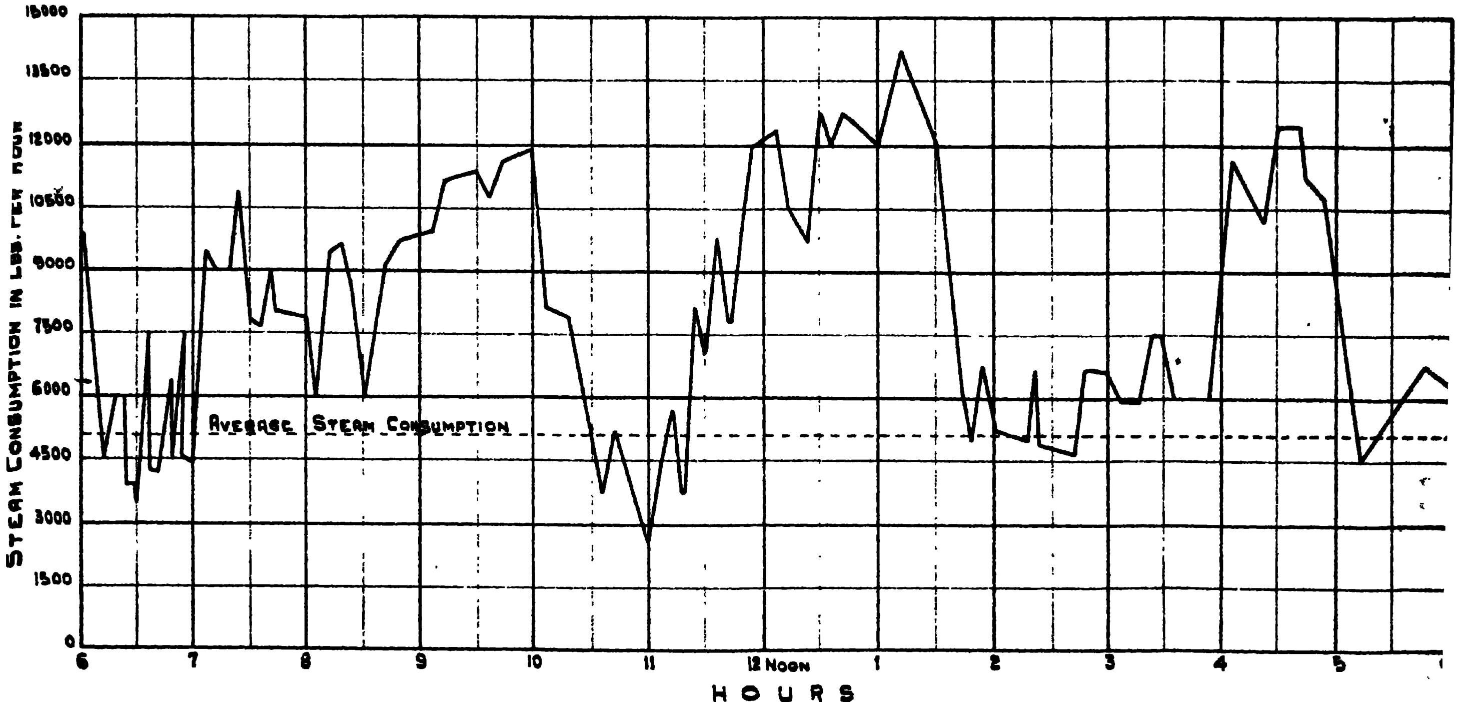


Plate No. 5.

Diagram showing heat and liquor flow in a quadruple effect evaporator in a Paper Mill.

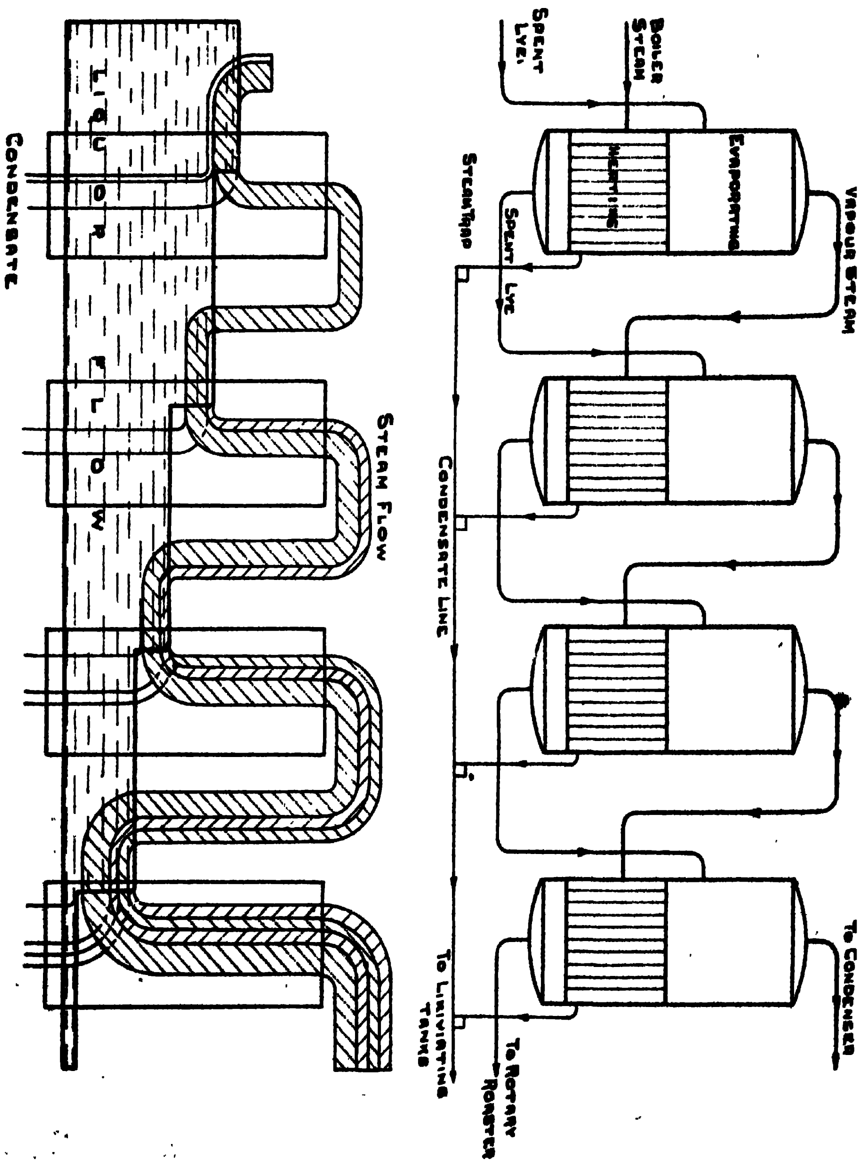


Plate No. 6.

Diagram showing total hourly steam consumption in a Paper Mill.

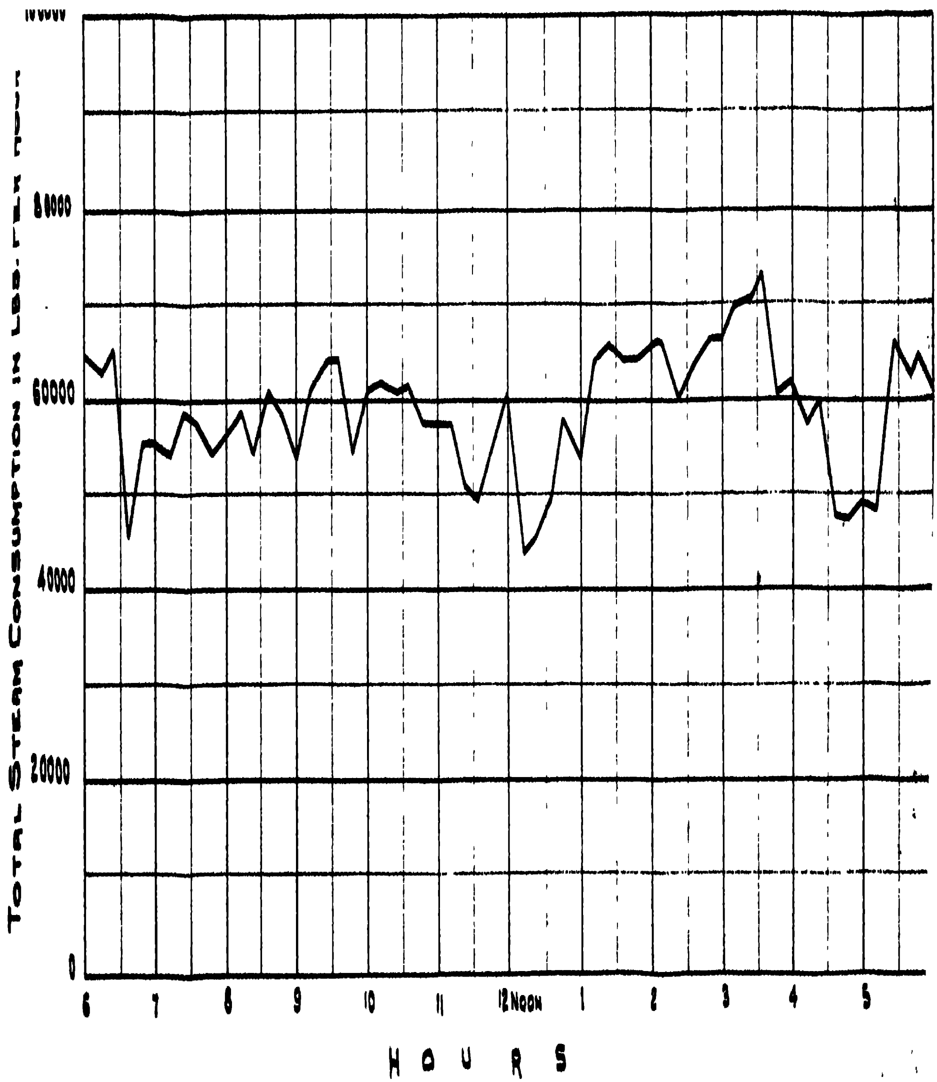
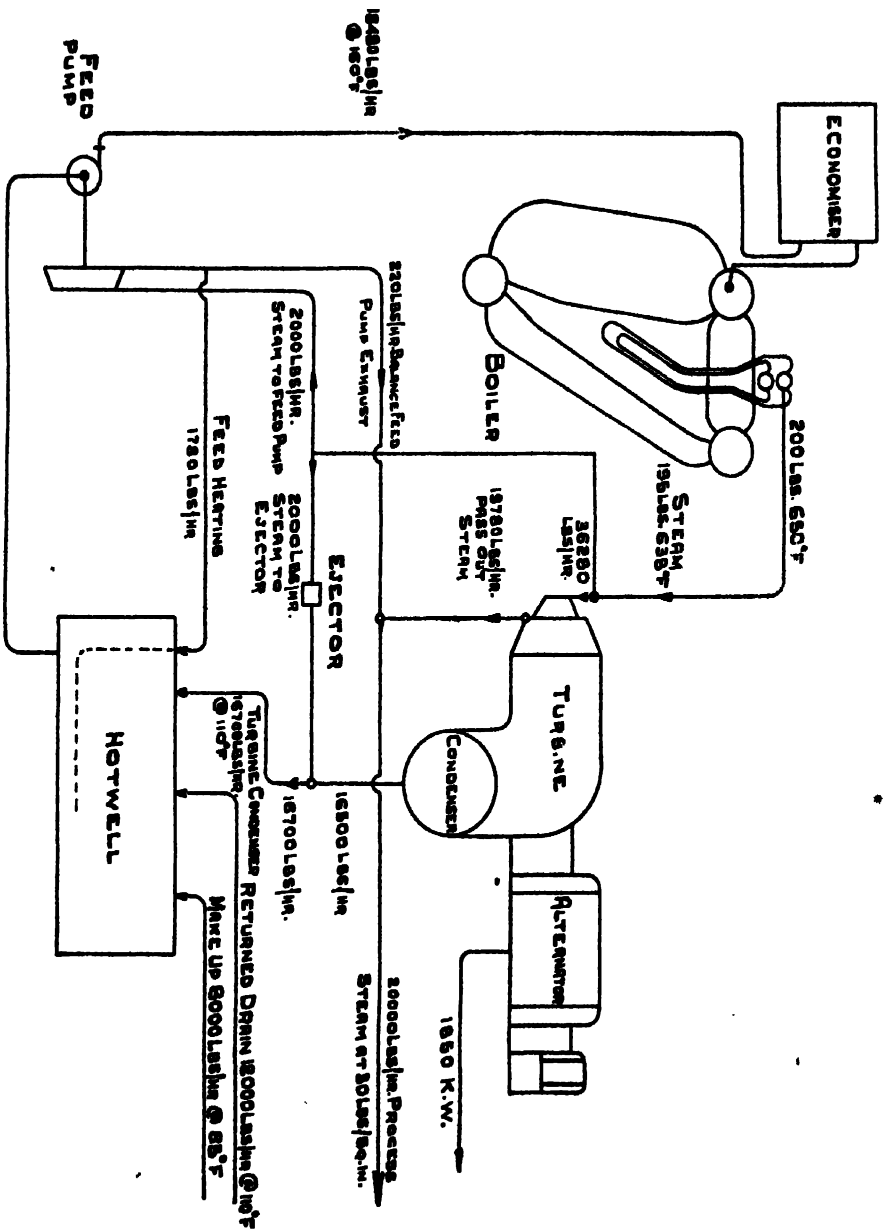


Plate No. 7.

Diagram showing heat flow in a combined power and heating system in a Paper Mill.



DISCUSSION ON
THE B. T. U. IN AN INDIAN PAPER MILL.

E. J.
hen.

MR. E. J. HOGBEN said that he was very grateful to Mr. Beattie for providing such an interesting paper. It contained much useful data on the working of a plant under the everyday conditions of a paper mill, wherein the conditions were perhaps unique. With constant boiler and condenser pressures, yet with presumably great variations in generator load, and with still greater variations in the demand for process steam, he should like to know how Mr. Beattie managed to control the steam supply. He visualised everything running smoothly when perhaps there was a sudden big quantity of steam "passed-out" of the turbine for process work. He inquired whether Mr. Beattie had a big ready reserve of boiler steam, whether *all* the process steam was passed through the turbine or whether peak process loads were made up direct from the boilers, and whether he found any difficulties in governing the system. If so, he would like Mr. Beattie to indicate their nature and how they were overcome.

. F. C.
nple.

COL. F. C. TEMPLE asked for further information regarding the precise track of the steam through the plant: whether it was correct that the steam which passed through the turbine, went to the condensers, or whether it performed any heating work on the way.

. R.
lfenden.

MR. R. WOLFENDEN congratulated Mr. Beattie on his very valuable and interesting paper and said that it was the type of paper he should like to see more frequently contributed to the Institution. He noticed from the curves the very large fluctuations in the rate of consumption of steam in the process work and also the variation in the total consumption per hour and inquired whether the use of a steam accumulator would not add greatly to the efficiency of the plant. He added that there seemed to be a very large percentage of oxygen in the Flue Gases and it appeared as if there was too much air going through the furnaces. He wished

to know if regular tests of the Flue Gases were made so as to see that only the right proportion of air was admitted. Mr. B. Wolfender

Prof. F. Sharpley.

PROF. F. W. SHARPLEY, in reply to a question of the Chairman regarding the use of low grade coal, said that the question of the relative heating efficiency of various grades of coal with regard to their cost was one rather outside his province but, with the permission of the Chairman he should be pleased to refer the matter to his colleague at Dhanbad, Prof. C. Forrester, who had done a large amount of work on Indian coals and who was particularly interested in this matter and in the necessity for the use of correct methods of sampling, a matter which was also touched upon in the paper. He would ask Prof. Forrester to submit a communication. Referring to the paper in general and to the possibility of generating cheap power in industries with requirements different from those of paper mills, Prof. Sharpley said that it might be of interest if he pointed out that in colliery working it was not an uncommon practice to drive the winder, and sometimes also the ventilating fan, direct by means of medium pressure reciprocating steam engines exhausting to an "exhaust" or "mixed-pressure" turbo-alternator with condenser. That method enabled full advantage to be taken of the heat contained in the steam before condensing and the cost of electrical power so generated was very low. The interesting feature was that in spite of the fact that the winding engine only worked intermittently a constant supply of low pressure steam could be arranged for the turbo generator by the use of steam receivers or accumulators. Even in the event of the winding engine being out of use for an abnormally long period a mixed-pressure turbine did not stop, for the automatic operation of the high pressure steam valve on it allowed steam at full boiler pressure to be supplied direct to the turbine until such time as the winder was again working at normal intervals. Thus a steady source of electrical power was available even though the direct steam load was a variable one.

Prof. C. Forreste

PROF. C. FORRESTER remarked that he had read with much interest Mr. Beattie's paper. He had for some years interested himself in the coals of India and in particular those of the Jharia and Raniganj coalfields. Mr. Beattie rightly stressed the importance of using the proper standard methods of sampling coal and that was of particular importance in India where the quality of a seam of coal and, therefore, of large individual lumps despatched as steam coal, might vary from foot to foot and even within a few inches. He had sampled many seams from roof to floor and could quote instances where the ash percentage in a seam varied from as little as 8% to as much as 25%, and yet the whole

seam had an average ash content of only about 11%. He was particularly interested in Mr. Beattie's statement, borne out by facts, that steam costs were very definitely in favour of the lower grade fuels. The following facts might add point to his statement. The table given below would show the actual number of heat units obtained for one anna when purchasing Indian coals of different qualities. The prices on which the results were calculated were those given in the 1932 edition of "Indian Coal Statistics, 1931", published by the Government of India. The technical data relating to ash percentages and calorific values, by means of which the number of heat units per anna had been calculated, were obtained by himself from an examination of the analysis of about 25 specimens of each type of coal. The table would show the number of heat units obtainable for one anna at the pithead and also the heat units obtained at destination about 170 miles away, the distance from Jharia to Howrah. If the calculations were made in respect of the shorter distance from the Raniganj field to Howrah the advantage in favour of low grade coals would be still more marked. The Government publication above referred to, however, did not quote prices for low grade "Raniganj" or "High Volatile" coals. The prices given therein together with the freight from either coalfield to Howrah, were considerably higher than Rs. 6 per ton quoted by Mr. Beattie. Presumably, therefore, the low grade fuels with which Mr. Beattie carried out his tests were obtainable at a very low cost indeed. It would be interesting to enter in the table below the data in respect of Mr. Beattie's sample also. Mr. Beattie gave the Calorific Value as 11,000 B.Th.U. That was much lower than the Calorific Value of any of the coals given in the table below. On referring to Mr. Beattie's first table he saw that there were 4 specimens having a C.V. below 11,000 B.Th.U. Of these, two were obviously Raniganj high volatile coals with high moisture content and two were low volatile coals but with a very high percentage of ash.

	COAL.	B.Th.U. per anna as received. At source.	170 miles from source (freight Rs. 4 per ton).
DISHERGARH.	Average, 12·5% ash, 2·78% moisture, C. V. 12,700 B. Th. U.	376,500	197,000
DO.	11% ash, 2·78% moisture. C. V. 12,400 B. Th. U.	379,000	201,000

Prof. C. Forrester.

COAL.		B.Th.U. per anna as received. At source.	B.Th.U. per anna as received. 170 miles from source (freight Rs. 4 per ton.)
JHARIA. Selected Grade.	13% ash (max. permissible), C. V. 13,260 B. Th. U.	463,900	237,000
Do.	12·5% ash (for comparison with Dishergarh coal), C. V. 13,380 B. Th. U.	466,000	238,000
Do.	11% ash (for comparison with Dishergarh coal), C. V. 13,550 B. Th. U.	475,000	242,600
JHARIA. Grade I.	15% ash (max. permissible), C. V. 12,960 B. Th. U.	557,000	249,000
JHARIA. Grade II.	18% ash (max. permissible), C. V. 12,480 B. Th. U.	873,000	291,000

The advantage in favour of the low grade fuel was not so striking at the distance chosen for the argument. In all cases, however, there must be some intermediate distance from which it would still pay to purchase low grade coals, even allowing for greater losses in ashes and clinkers. He did not quite agree with Mr. Beattie when he made the following statement:—

> "..... the smaller grades of coal (unless they are well washed) have naturally a lower calorific value owing to the higher percentage of foreign matter they contain."

That statement was true generally of British coals but he had found, and many mining engineers in India were also familiar with the fact, that the smaller grades of Indian coals (at least of Jharia coals) were of better quality than the run-of-mine coal, except in cases of machine-mined coal where the machine had been cutting in the floor. Indian coals in both the Jharia and Raniganj fields contained many bands of bright coal which was very friable. In

the course of mining and bringing to the surface these broke up and remained with the small coal. The ash content in the bright coal was of the order of 3%, as compared with the usual ash content of 12% to 16% in run-of-mine coal. The difference in ash content of the various sizes varied but was usually as much as 3 or 3·5%, i.e., run-of-mine coal having about 12% of ash would frequently give a slack containing only about 9% of ash. He did not suggest, of course, that that was always so, but he had the records of many analyses made by himself and knew of similar records that were maintained at colliery laboratories in the field.

MR. J. PRATT said that all industrial engineers should be greatly indebted to Mr. Beattie for his interesting and valuable paper where he was able to show that even with ordinary boiler efficiencies ranging from 64% to 72%, an overall thermal efficiency for power of 27·2% could be obtained, a result which he stated compared favourably with the best super power stations. The paper would be of greater value however if it could be shown what plant renovations were carried out to obtain the results shown on Page 72 as presumably the figures shown under Stage 3 were not only aimed at but actually realised. Stage 1 apparently represented a period when an old prime mover was in use but Stages 2 and 3 related to the working of the same turbine, the only difference being that in Stage 3 the load was increased from 1,880 K.W. to 2,030 K.W. while slightly more process steam at 30 lbs. was bled from the turbine and the independent supply of process steam at 80 lbs. was approximately halved. The economy effected by substituting a new turbine for the prime mover mentioned in Stage 1 and at the same time increasing the boiler pressure, the feed water temperature and the superheat could be understood especially as an arrangement to bleed steam at 30 lbs. from the new turbine was included but it would be of great advantage to all industrial engineers to know what changes were effected between Stages 2 and 3 to produce a yearly saving of 6,500 tons of coal with an all-round increase in efficiency and a slight increase in the power load, and with the paper output of the Mill as it was in Stage 2. On page 68 the author confessed to a feeling of depression when he considered the efficiency of his boilers but no engineer need feel discouraged if he could produce results such as were shown on page 72. The author stated on page 68 that "Steam generating costs

were very definitely in favour of the lower grade fuels." This appeared to be an unorthodox view but if it was correct it was surprising that coal of even lower grades was not used than those referred to on page 65 where the values ranged from 10,510 to 12,860 B. T. U. It was unnecessary to add that these observations were made solely to be quite clear about the methods adopted by Mr. Beattie so that other engineers might copy his example and try to obtain similar economical results. Mr. J. Pratt.

THE AUTHOR, in reply to Mr. Hogben's remarks, said that the plant operating conditions in a paper mill were perhaps of more than ordinary interest. In this instance the power load remained reasonably steady throughout the 24 hours, without anything in the nature of serious peaks occurring subject to the usual momentary rise when starting heavy motors. The governing on the power side was therefore a normal procedure. The particular feature of the governor gear for an extraction turbine consisted in the provision of additional controlling valves regulating the admission of steam to the lower stages of the turbine. These low pressure controlling valves were operated by a servo motor and cam gear, generally similar to that employed for the high pressure valves, the oil of the low pressure servo-motor being regulated by a separate pilot valve under the control of a pressure regulator. The function of that regulator, which was connected to the heating steam chamber, was to cause the low pressure controlling valves to open if the heating steam pressure should rise above the desired figure, and to close the low pressure control valves if the heating steam pressure should fall. The action of the low pressure control valves being liable to cause fluctuations in speed, which would lead to difficulties in parallel operation if not guarded against, the high pressure and low pressure valve gears were connected to each other and to the speed governor and pressure regulator in such a manner that if the low pressure valves should close in response to a drop in heating steam pressure caused by a demand for heating steam, the high pressure control valves would open to an extent sufficient to supply the required additional heating steam, and to do the additional work on the first stage wheel to compensate for the loss of extracted energy from the low pressure stages. Similarly, should the demand for heating steam decrease, causing a rise in heating steam pressure, the consequent opening of the low pressure control valves would be accompanied The Author.

Author. by a corresponding closing of the high pressure control valves. In this way, the speed governor was not affected by variations of demand for heating steam, and parallel operation could be satisfactorily carried out. In the event of changes in load, the high pressure and low pressure control valves moved in the same direction, thus tending to maintain a constancy of pressure at the heating steam outlet. It was when dealing with the control of steam demand for the mill that the problem asserted itself. Very heavy steam peaks of from 30 minutes to one hour's duration were a common feature, and these demands had to be met without a corresponding steam pressure drop if economy of operation was to be maintained. The average quantity of process steam, at 30 lbs. gauge, extracted from the turbine was something like 17,500 lb. per hour with an average power load of 1,880 kw. As the turbine was designed for a maximum extraction of 35,000 lb. at 2,500 kw., or full load, it would be seen that there was an ample margin available to deal with very heavy peak loads in the extraction section of the steam belt. On the other hand, the greatest variations in process steam demand took place at the higher pressure of 80 lbs. gauge, and had to be met by the boilers direct via steam pressure reducing valves. Here again they were fortunate, in that the boilers had a liberal rating, which permitted of heavy peak loads being met by an increase in the speed of the chain grates and damper control, the capacity of the chimney on induced draught being much greater than for present requirements.

Dealing with Col. Temple's remarks and his question regarding the precise track of the steam through the plant the author said that there was much in his reply to Mr. Hogben that was apposite to Col. Temple's inquiry. He would also add that the mill used steam in two separate systems and generated its steam in a common boiler plant, the evaporation of 62,100 lbs. per hour taking place at 200 lb. gauge, and the steam was superheated to 250 degs.F. 67·5 per cent or 41,900 lbs. was fed to process departments, as follows:—23,300 lbs. through a reducing valve the pressure on process side being 80 lb. gauge, and 18,600 lbs. by expanding steam through a 2,500 kw extraction turbo-alternator set, the pressure at extraction point being 30 lb. gauge. 32·5 per cent or 20,200 lbs. went to the condenser with a terminal

pressure of 27·5 in. vacuum; the full load steam consumption was 19 lb. per kw and the normal load on the set was 1,880 kw. The condensate was returned to the boilers and the temperature of the boiler feed was raised to 162 degs. F., by means of returns from process, etc. The total heat of steam at 200 lb. gauge, plus 250 degs. F. superheat equalled 1,334 B.Th.U. and the total heat input per lb. equalled 1,204 B.Th.U. The total heat input per hour with boiler efficiency of 72 per cent was therefore $62,100 \times 1,204/0·72$ or $103·85 \times 10^6$ B.Th.U. per hour.

The Autho

With regard to Mr. Wolfenden's remarks the author said that his reference to the very large fluctuations in the rate of consumption of process steam and the possibilities of a steam accumulator adding to the efficiency of the plant was much to the point. The installation of an accumulator of sufficient capacity to deal with the greatest fluctuations in process steam demand, and to "bridge" the periods necessary to the boiler plant being adjusted to meet the altered load conditions would certainly tend to increase the general efficiency of the plant. The use of a double pass-out turbine would also help matters as the power load was practically constant, and if the extra steam required to meet process peak conditions were extracted from the high pressure stage of the turbine it would lessen the demand on the boiler, as every kwh produced under back pressure working conditions saved a kwh to be generated under condensing conditions, due allowance being made for the difference in steam consumption per kwh at the corresponding points in the heat gradient. Perhaps the simplest solution of the difficulty was to preheat the liquids used in the process departments, by the use of by-product exhaust steam, preferably at or near atmospheric pressure, as by far the greater percentage of peak loads in heating steam systems were incurred in the initial heating of comparatively cool liquids to the temperatures suitable to process requirements. The question of excess air passing through the fuel bed was one that was much in evidence in most boiler houses and in the absence of permanent instruments, as an aid to combustion control, it was difficult to adequately check all avoidable losses. A wide range of boiler house instruments was now available and one might hope that the day was not far distant when their application would become standard practice, even on individual boiler units.

Author. Dealing with Professor Sharpley's remarks on the possibility of generating cheap power in other industries the author said that they were very much on a par with his own experience on plants of a similar description. The author cited three instances, viz. (1) in an explosives factory, where high speed compound engines driving D.C. generators exhausted direct into a mixed pressure turbo-generator set; (2) in a steel works, where rolling mill engines exhausted to a mixed pressure turbo-alternator set, via a steam accumulator to "bridge" over the intermittent periods unavoidable in the operation of rolling mills; (3) in a small colliery where high speed compound engines running non-condensing and driving D.C. (generators were replaced by a mixed pressure geared turbo) generator set, supplied with exhaust steam from the colliery winders, ventilating fan, and coal washery plant, via an accumulator composed of old Lancashire boilers. Prior to the installation of the mixed pressure turbo set three Lancashire boilers, fired with the usual "duff" from the washery and a percentage of screened nuts—grudgingly given—were steaming hard on the power plant, with sometimes the fourth boiler brought into service. When the new plant was put into commission it was found that one Lancashire boiler was sufficient to steam the power unit, with a second boiler on banked fires as a standby. In a modern colliery and brickworks with mixed pressure turbo-alternator sets operating under similar conditions excellent results were also obtained.

The author much appreciated Professor Forrester's remarks which, he said, added considerably to his knowledge of a raw material, the cost of which was an important item in the production of paper. For instance, in the plant under review the annual coal consumption was something like 75/80,000 tons, and taking the latter figure as a basis, a saving of only one per cent meant 800 tons per annum. Now even 800 tons coal per annum could be a fairly useful contribution to a reduction in costs of production and if this could be increased five times—or, say, 5 per cent of the total—the savings would become 4,000 tons, a figure which was an excellent inducement to increased efficiency. By a suitable selection of fuels, an industrial boiler plant operating at, say, 70/72 per cent efficiency

offered the possibility of realizing that extra 5 per cent and its obvious advantages without incurring added liabilities in the form of increased maintenance charges. The author was glad to note that the data submitted by Prof. Forrester supported his own experience of the advantage in using a selection of the lower grade coals or economy in steam raising. This was confirmed by the addition to Mr. Forrester's table of certain coals used by the author on a series of tests, the railhead being Ondal Junction, and the distance to Titaghur, 109 miles.

COAL.		B.Th.U. per anna as received.	
		At source	170 miles from source (freight Rs. 4 per ton).
DISHERGARH.	Average, 12·5% ash, 2·78% moisture, C. V. 12,700 B. Th. U.	376,500	197,000
DO.	11% ash, 2·78 moisture, C. V. 12,400 B. Th. U.	379,000	201,000
JHARIA. Selected Grade.	13% ash, (max. permissible), C. V. 13,260 B. Th. U.	463,900	237,000
Do.	12·5% ash, (for comparison with Dishergarh coal), C. V. 13,380 B. Th. U.	466,000	238,000
Do.	11% ash, (for comparison with Dishergarh coal), C. V. 13,550 B. Th. U.	475,000	242,600
JHARIA. Grade I.	15% ash, (max. permissible) C. V. 12,960 B. Th. U.	557,000	249,000
JHARIA. Grade II.	18% ash, (max. permissible) C. V. 12,480 B. Th. U.	873,000	291,000

Author.

	COAL.	At source.	109 miles from source (freight Rs. 3-7 per ton).
RANIGANJ.	30·71% ash, 0·95 moisture C. V. 10,621 B. Th. U.	580,269	247,823
DO.	24·39% ash, 4·46 moisture C. V. 10,716 B. Th. U.	585,449	250,040
DO.	15·08% ash, 7·51 moisture C. V. 11,223 B. Th. U.	613,159	261,870
DO.	12·26% ash, 10·23 moisture C. V. 11,458 B. Th. U.	625,998	267,353
DO.	15·40% ash, 8·83 moisture, C. V. 11,639 B. Th. U.	635,887	271,576
DO.	14·82% ash, 5·56 moisture, C. V. 12,052 B. Th. U.	658,451	281,213
DO.	14·41% ash, 4·40 moisture, C. V. 12,517 B. Th. U.	683,855	292,063

The author accepted Prof. Forrester's view regarding the calorific value of the smaller grades of coal, particularly in India, as his very wide experience in the grading and sampling of coals constituted him an authority on the subject.

In dealing with Mr. Pratt's remarks the author first of all referred to steam generation costs in relation to the lower grade fuels. That such costs were definitely in favour of this class of fuel was proved in actual practice on the plant under review, although at first sight this might seem an unorthodox view. It was largely a matter of judicious mixing or blending of the grades available and the all important question of price. It also did not follow that the very lowest grade coals, of themselves, would maintain the economic ratio.

Referring to page 72 of the paper, Stage 1 did represent a period when an old prime mover was in use, and Stages 2 and 3 referred to the operation of a new turbine, i.e. a 2,500 K.W. single stage extraction unit.

In obtaining a saving of 6,500 tons of coal per annum various improvements contributed to this result. For instance, an improved boiler efficiency of 3 per cent was equivalent to a yearly saving

of 1,043 tons; an increase of 2·95 per cent in turbine pass-out steam for process use, to a yearly saving of 1,025 tons, while the balance of 4,450 tons was due to improved methods of heat economy in the steam using plant of the process departments and represented something like 0.5 ton per hour. The problem was simply how to make the fullest use of the *latent* heat of the steam supply to the purely heat-using machines. Steam using equipment in a paper mill was very extensive and there was a wide field for the introduction of economies, particularly in local back-pressure operation and heat recovery as applicable to the paper making machine, an example of which was given on page 73 of the paper under the heading of Process Steam Uses. The same applied to steam used for the digester department, but the subject was really too extensive to be dealt with here and he should be glad to give fuller details on another occasion. The Auth

TEMPERATURE STRESSES IN REINFORCED BRICKWORK
AND
THE FAILURE OF REINFORCED BRICKWORK ROOFS

BY

Professor RAJA RAM, Associate Member,

and

Mr. ANAND SAROOP.

In the design of Reinforced Brick Roof Slabs usually the same assumptions are made as those in the case of Reinforced Concrete slabs; only the values of constants used in the former differ from those used in the case of the latter.

The assumptions usually made are :—

(1) A plane section before bending remains plane after bending.

(2) Tension is entirely borne by steel.

(3) Initial stresses in steel are absent.

(4) The composite material is homogeneous within elastic limits.

(5) Adhesion between concrete and steel is perfect within elastic limits as also the adhesion between the component materials of the concrete

and (6) Co-efficients of expansion of steel, concrete and bricks are very nearly equal.

The values of constants used generally in the design of reinforced concrete and reinforced brickwork are given on next page.

Constants	Working values for reinforced concrete. (1 : 2 : 4) mix.	Working values for reinforced brickwork. Values given by Brebner.	Values obtained experimentally by Prof. Salig Ram vide Indian Engineering of 11-5-1929.
fs	16000-18000lb./in²	16,000lb./in² 20,000lb./in²	
	Usually 650lb./in² 600-1000 lbs./in² according to the mixture of concrete used	300-350lb./in² for slabs 250 lbs./in² for beams	Same as Brebner's
$\frac{E_s}{E_c} = n$	15	40	80 for Roorkee bricks.
bond	80-120lbs./in²	80-90lbs./in²	
Tensile strength of concrete.	1/10th of its compressive strength.		
Shear	60	60lbs./in²	
Diagonal tension	Usually 40lbs./in²	40lbs./in²	
Co-efficient of expansion for steel	0.0000055 per degree F		
Co-efficient of expansion for concrete	do.		
Modulus of elasticity for bricks		375000lbs./in²	375000lbs./in²
E_s E_c	30×10^6lbs./in² 2,000,000lbs./in²	2,000,000lbs./in²	

On page 29 of Technical Paper No. 38—Notes on Reinforced Brickwork Volume I by A. Brebner it is stated that "Temperature stresses may be neglected in the construction of all ordinary structures. The matter has not yet been fully investigated, but practice shows that the stresses in ordinary work are generally insignificant, provided slabs of a suitable depth are chosen having regard to the span." It is thus evident that this item has been left uninvestigated by engineers so far.

As cracks have appeared several years after their construction in the Reinforced Brick roof slabs of buildings erected at Patna, Benares Hindu University, Delhi and in Central Provinces, it is desirable to investigate the possible causes of these cracks and consequent partial failure.

At the outset it must be recognized that the adhesion amongst Brick, Concrete and Steel in R. B. work cannot be as good as in Reinforced Concrete, for there is very little in Reinforced Brickwork, to exactly correspond to the shrinkage in the setting of the concrete around steel in Reinforced Concrete. Similarly, the bond between bricks and cement mortar or cement concrete in the joints of Reinforced Brickwork cannot be evidently quite as good and strong, as in the case of cement concrete of Reinforced Concrete work.

One of the obvious causes of failure of Reinforced Brickwork may lie in the difference between the co-efficients of expansion of steel, brick and cement concrete. The authors of this paper therefore decided to determine correctly values of co-efficients of expansion for 1 : 3 (well set, 2 to 6 months old) cement mortar, burnt mud bricks and steel commonly used for Reinforced Brickwork in India. With this end in view the experiments described in the appendix to this paper were undertaken.

The burnt mud bricks used were specially selected well burnt first class bricks 17 7/10″×5″×2 4/5″ though they were intended to be 18″×5″×3″, The cement concrete bricks were 18 9/10″×5 4/5″×3 4/10″ and the ratio of cement to sand in them was 1 to 3. The sand used was the Dehra Dun Rispana coarse sand and the cement was a well-known British Brand of Portland Cement.

The ranges of temperature selected for the experiments were (1) 30°C—8°C (2) 30°C—60°C and (3) 30°C—80°C or in degrees Fahrenheit (1) 86°—46.4°F (2) 86°—140°F and (3) 86°—176°F. The main reason for selecting these ranges was that the probable extreme figures for maximum and minimum ranges of temperature at various places corresponded to them.

At the request of one of the authors, the Director-General of Meteorological Observatory, Poona, very kindly supplied the following mean extreme figures.

		Temperature. Maximum in the Sun.	Temperature. Minimum in the open.
Delhi	...	159°F	39°F
Lucknow	...	163°F	36°F
Lahore	...	166°F	32°F
Nagpur	...	167°F	40°F
Patna	...	146°F	46°F
Benares	...	162°F	37°F

The co-efficients of expansion for the specially selected well burnt mud brick, 1:3 cement mortar brick, and steel were experimentally found to be as follows:—

	Range.	Co-efficient of expansion.
Well Burnt Specially Selected Mud Brick	8°—34° and 34°—65°C	0.0000083 per degree Fahrenhei
Cement Concrete brick of 1:3 cement & sand proportion	22°—75°C	0.0000056 per degree Fahrenheit.
Round Iron bar (Tata's)	20°—86°C	0.000006 per degree Fahrenheit.

From the figures given above it is evident that the difference between the values of the co-efficients of expansion of specially selected brick, and cement and sand mortar=0.0000027

Specially selected brick and steel=0.000023 per degree F

Cement and sand mortar, and steel=0.0000004 per degree F

Therefore expansion of Roorkee brick is 48.2 per cent or nearly 1½ time greater than that of cement mortar brick.

The stresses produced in bricks of a reinforced brickwork slab or beam due to variations of 60°F, 80°F, 100°F and 134°F temperatures above or below the temperature at the time of construction are shown below. The stress is calculated from the formula $E = \dfrac{\frac{F}{a}}{\frac{l}{L}}$ or $\dfrac{F}{a} = E\dfrac{l}{L} = E\dfrac{L\,(d.t)}{L} = E.d.t$ where a = Sectional area; F = Total Stress; L = length; l = elongation; d = co-efficient of expansion; t = range of temperature.

60°F			80°F			100°F			134°F		
Expansion of mud brick.	Expansion of C. S. mortar brick 2—6 months old.	Stress produced by change of temperature.	Expansion of mud brick.	Expansion of C. S. mortar brick.	Stress.	Expansion of mud brick.	Expansion of C. S. mortar brick.	Stress.	Expansion of mud brick.	Expansion of C. S. mortar brick.	Stress.
·00498 ft.	·00336 ft.	60·75lbs./in.	·00664 ft.	·00448 ft.	81lbs./in.^{2}	·0083 ft.	·0056 ft.	101·25lbs./in.^{2}	·011122 ft.	·007504 ft.	135·675lbs./in.^{2}
= ·05976 in.	= ·04032 in.	8748lbs./ft.^{2}	·07968 in.	= ·05376 in.	= 11664lbs./ft.^{2}	= ·0996 in.	= ·0672 in.	= 14580lbs./ft.^{2}	= ·133464 in.	= ·090048 in.	= 19537lbs./ft.^{2}

From the above table it is evident that an additional maximum tensile stress of 60.75 to 135.675 lbs/in^2 due to variations of temperatures may be produced in the body of the Reinforced Brickwork between burnt bricks, and cement and sand mortar. This alone would warrant the failure of Reinforced Brickwork. However the variation of temperature stress from a minimum to a maximum during each 24 hours will, as usually happens, reduce the safe working stress. Such variation is repeated 365 times each year. In 10 years the repetitions will number 3,650. Although the effect of repetition and reversal of maximum and minimum stresses on brickwork has not been so far investigated it is evident that this will tend to lower the safe working stresses for these materials.

It is therefore evident that in most cases the failure of Reinforced Brickwork can be traced to the stresses caused by temperature variation and the difference in co efficients of expansion of the materials used.

It may perhaps be pointed out to the authors by some engineers that in spite of such great stresses produced by variations of temperature there are many reinforced brick roof slabs in this country which are still in sound condition many years after erection. The authors would like to explain that the sound condition of such reinforced brick roof slabs may probably be due to the following factors:—

(1) Such roof slabs are probably never subjected to the full super or external load of 20—100 lbs. per sq. ft. for which they are designed and therefore the adhesive and shear strengths of materials are sufficient to withstand temperature changes though possibly with hardly any factor of safety.

(2) The co-efficient of expansion of the bricks may be smaller than that of Roorkee bricks.

(3) The slabs may be deep and of small spans.

(4) The modulus of Elasticity of such bricks may be different from those of Roorkee bricks.

(5) Owing perhaps to protection afforded by shade and surface coating their roof slabs may not be exposed to the same ranges of temperatures, and if they are, their conductively may not permit of the heat affecting the interior parts of the roof slab. The latter point can be experimentally investigated.

(6) In some such roof slabs, the range of stress and the number of reversals required for failure due to the conditions mentioned in (5) above may not have yet been attained.

The details of experiments for determining the co-efficients of expansion are given in the Appendix to this paper.

The authors were very anxious to experimentally determine the co-efficients of expansion of materials in an actual Reinforced Brick slab of 5 to 10 feet span, but circumstances beyond their control prevented them from doing so.

It would be interesting to find out the co-efficients of expansion of bricks made at various important places in India, and also of cement and sand mortar bricks of varying proportions of sand made with rapid hardening, ordinary and special cements, and sands of various places of varying sizes of particles and compositions.

In concluding, this paper, the authors would like to mention that they are fully conscious of the fact that they have attempted by these experiments to touch merely a fringe of the problem according to the limited facilities they could squeeze out for themselves in an institution which is not primarily equipped for these purposes. It would be a most desirable thing if similar facilities for this kind of work were available in India as at Watford Building Research Station near London.

It would interest the authors if other persons or bodies in India with better apparatus and more leisure and money at their disposal could further investigate this problem, and in greater detail. As roofs of buildings erected in this style have cost many lakhs of rupees, in India, and as Reinforced Brickwork design is more frequently resorted to for the sake of cheapness and convenience in construction such information will be most useful.

APPENDIX

The experiments described herein were carried out in the Physics Laboratory of the Thomason Civil Engineering College, Roorkee, during the months of June to November, 1932 with a view to determining the co efficients of expansion of steel, 1 : 3 cement and sand mortar brick, and specially selected 1st class kiln burnt mud brick. These form the component materials of Reinforced Brickwork.

Two methods were tried for obtaining requisite ranges of temperature.

Firstly, the bricks were immersed in a water bath for obtaining desired ranges of temperature but as bricks absorbed considerable quantity of water during the period of their immersion in the bath, the results obtained were found to be unreliable. Therefore an indirect method of heating the bricks by radiation was tried and found satisfactory.

This method of heating involved the placing of the brick in a water tight rectangular iron plate box which enclosed it on all sides. This box containing the brick was placed in a water bath the temperature of which was controlled by heating it with gas burners or cooling it with ice as circumstances demanded.

The arrangement is illustrated in the two accompanying photographs pages 113 & 114. A brick prepared for experiment is shown in the first photograph. This brick was mounted on rollers with end guides to prevent lateral displacement. Three holes each 5/8" in diameter and about 2" deep (one in the centre and the other two spaced 6" from the centre one on either side of it) were drilled in each brick. At either ends of the brick were fastened iron plates carrying uprights marked AA in photograph I. The iron plates had on their outer faces three wedges round which a string was wound to keep the plate in contact with the brick. The faces of the bricks and plates were planed in order to provide good contact between the surfaces of the brick and plates. To prevent lateral displacement of the plates, the plates were equipped with two projecting pins, each fitting into a hole drilled in the ends of the brick. The plates were fastened to the brick and uprights by means of a string passing over the entire area of brick surface as shown in the accompanying photograph I. Three thin glass test tubes containing mercury were inserted in the three holes of the brick. In each of these glass test tubes containing mercury was placed a thermometer to indicate the temperature of the brick. The range of temperature, as mentioned before varied from 8° to 86°C in these experiments. When the three thermometers

gave practically the same reading for about 2 hours, the elongation or contraction of the brick was measured by means of optical levers.

The optical lever consisted of a frame abcd (as indicated on the first photograph) which carried a bar '*ef*' hinged along the centre line of the frame. The lever L projecting at right angles to the rod 'ef' carried the screw N, the end point of which rested against the planed surface of the uprights AA fixed to the brick. The rod 'ef' carried a mirror M fixed rigidly along the axis of rotation of 'ef.'

The magnification* obtained from an optical lever is $\frac{2r}{D}$ where r=distance between the mirror and the reflected image of the wire on the vertifical scale and D=Length of the optical lever, which is the distance between the axis of bar 'ef' and the end point of screw N (See photograph 1.).

The uprights projected upwards through the holes in the iron plate box enclosing the brick, to a distance of about 2″.

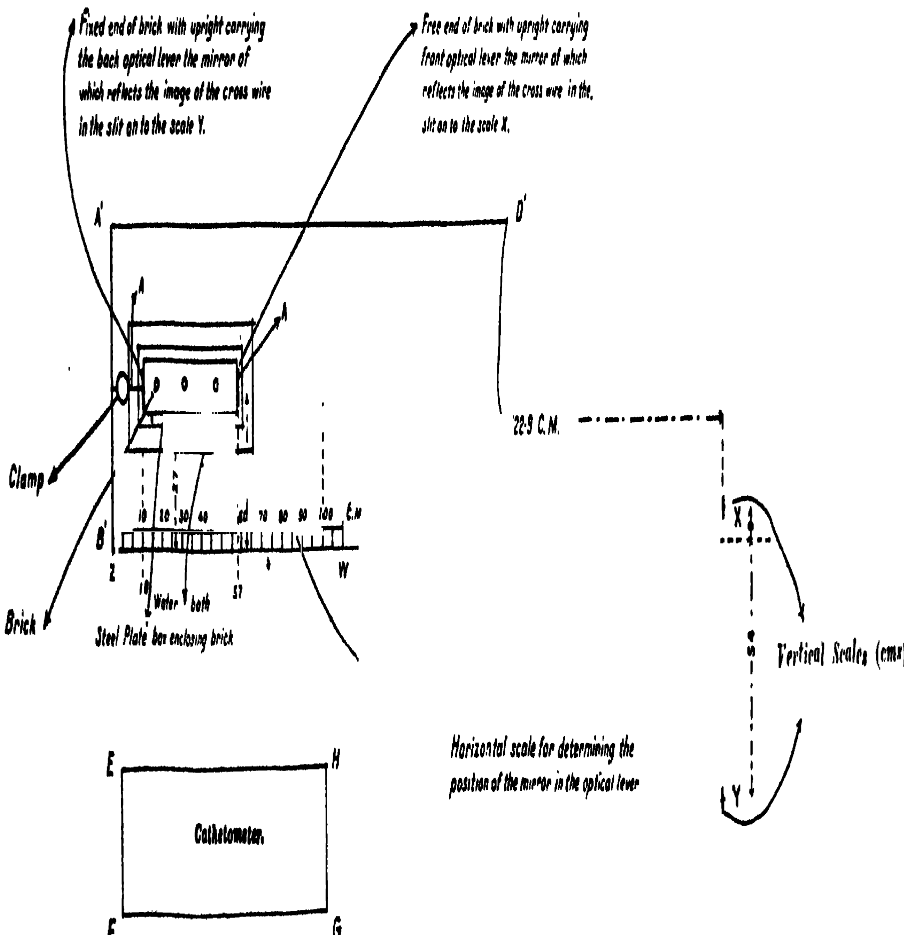
The end point of the screw N was made to press against the upright by means of two springs S.S. on the free end of the brick. A similar arrangement for the sake of precaution was provided at the other end of the brick. One end of the brick was fixed and the other allowed to move.

When expansion or contraction of the brick took place the free upright was displaced and with it the end point of the screw N, thus rotating mirror M. A beam of light through a slit containing a horizontal wire, parallel to its inner edges was thrown on the mirror of the optical lever. After reflection from this mirror the image of the wire was focussed on a vertical scale. The upward and downward motion of the image of the wire on the scale indicated the amount of magnified elongation or contraction of the brick. The magnification of elongation or contraction obtained by this means was 240.

In order to obtain readings of the elongation or contraction of the brick on the vertical scale a cathetometer was set up parallel to another scale Z W fixed on the edge of the table on which the apparatus and the brick were placed as shewn in the second photograph. The general plan of the arrangement of the apparatus is given below :—

*When a beam of light is reflected from the mirror M and the mirror is rotated through an angle θ, this reflected beam turns through $2\ \theta$. If r be the distance of the scale on which the beam of light is made to move, d. the distance on the scale through which reflected image of wire moves, the angle turned through by the mirror = d/2r. If D be the distance of the end of the pointer from the axis of rotation, the distance through which the pointer moves = dD/2r. In the experiment D was approximately 5 cm, r = 600 cm. so that the magnification = 2r/D = 2 × 600/5 = 240.

PLAN SHOWING ARRANGEMENT OF APPARATUS



Scale 30 cms = 1'

Raja Ram
B.Sc., A.M., Inst.C.E.

A' B' C' D' is a table top
A.A. uprights.
E.F.G H another table for cathetometer

All measurements were made in centimeters and degrees centigrade.

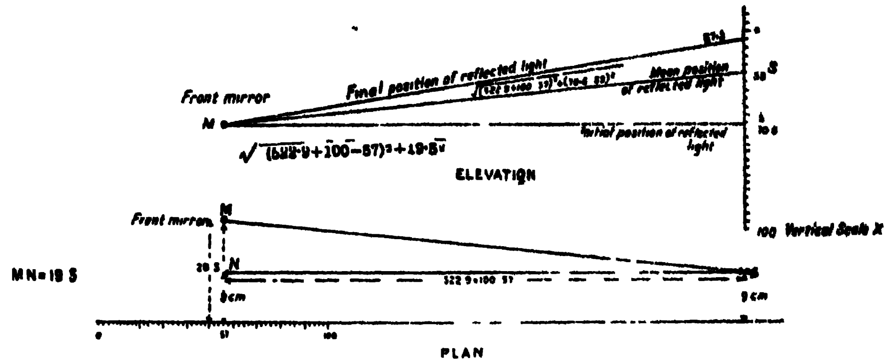
The following example shows the method of calculating the result from the readings obtained during the course of the experiment:—

Date.—27th June 1932.

1. Distance of the 100th division on the scale ZW from the line of vertical scales X and Y ... 522.9 cm.
2. Vertical position of the axis of front mirror along the scale ZW ... ... 57.0 cm.
3. Do. for the back mirror ... ... 10.0 cm.
4. Reading on vertical scale for front mirror level with the axis of the mirror before elongation or contraction ... ... 70.6 cm.
5. Do. for back mirror ... ... 32.8 cm.
6. Horizontal distance of front mirror from scale ZW ... ... 28.5 cm.
7. Do. for back mirror ... ... 27.5 cm.
8. Horizontal distance of scale X from edge of table ... ... −9.0 cm.
9. Do. for scale Y for back mirror ... ... 54.0 cm
10. Length of front optical lever from the axis of rotation to the end point of the screw N= D= 5.7 cm.
11. Do. for back mirror ... ... 5.0 cm.
12. Length of brick at ordinary temperature ... 44.85 cm.
13. Initial temperature ... ... 34.3°c.
14. Final temperature which after heating for 2 hours remained constant ... ... =63.3 cm.
15. Initial position on scale X of reflected light from front mirror ... ... 61.3 cm.
16. Final position of reflected light from front mirror ... ... 57.3 cm.

Mean. ditto ditto ... 59.0 cm.

17. Initial position of reflected light from back mirror	...	...	...	51.9 cm.
18. Final	ditto	ditto	...	50.6 cm.
Mean	ditto	ditto	...	51.2 cm.



$$Ms^2 = (522.9+100-57)^2+(19.5)^2$$

Mean length of reflected beam from front mirror $= \sqrt{Ms^2+Ss^2}$

$$= \sqrt{(522.9+100-57)^2+19.5^2+(70.6-59)^2}$$
$$=566.3 \text{ cm.}$$

Similarly mean length for beam from back mirror = 617.3 cm.

Expansion is equal to the difference between the distance through which the ends of the pointers move resting against the the brick move.

Expansion $= \dfrac{d''D''}{2r''} - \dfrac{d'D'}{2r'}$ (For explanation see foot note on page 108.)

$$\therefore \text{Expansion} = \frac{4\times 5.7}{566.3\times 2} - \frac{1.3\times 5}{617.3\times 2}$$
$$= .0161 \text{ cm.}$$

Co efficient of expansion $= \dfrac{.0161}{44.85\times 29} = .000012°$ per degree centi grade.

A thermostat was used for maintaining the temperature of water bath constant for only the middle range—its range being such as not to permit its use for the other ranges. Heating was done by gas burners. Readings were, in all cases, taken when the temperature of the brick was fairly constant for at least two hours as mentioned previously and each reading took from 6 to 8 hours

RESULTS.

Date.	Material	Range	Coef. of Exp. per C.	
June 14, 1932.	Burnt Mud Brick.	8—34 C	.000014	Mean .000015 or .0000083 per F.
July 7, 1932	do	8—29 C	.000016	
June 27, 1932	do	38—65 C	.000012	Mean .000015
July 1, 1932	do	30—55 C	.000019	
Oct. 21, 1932	1 : 3 Cement Sand Mortar Brick. (2—6 months old)	25—36 C	.0000118	Mean .0000101 or .0000056 per F.
Oct. 28, 1932	do	23—75 C	.0000092	
Oct. 31, 1932	do	22—75 C	.0000093	
Nov. 11, 1932	Round Steel	23—86 C	.0000106	Mean .0000107 or .000006 per F.
Nov. 16, 1932	do	20—79 C	.0000108	

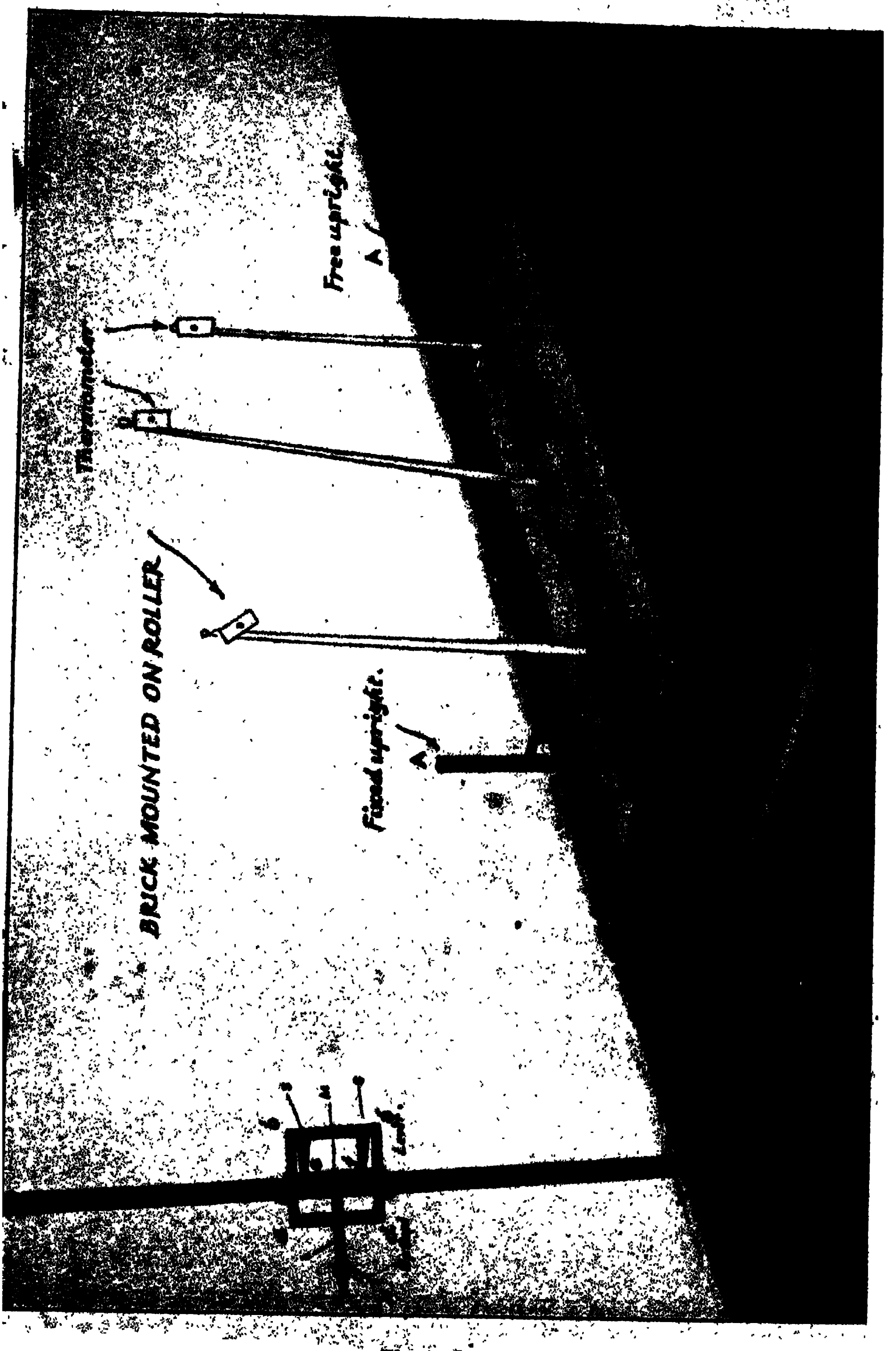


Photo. 1.

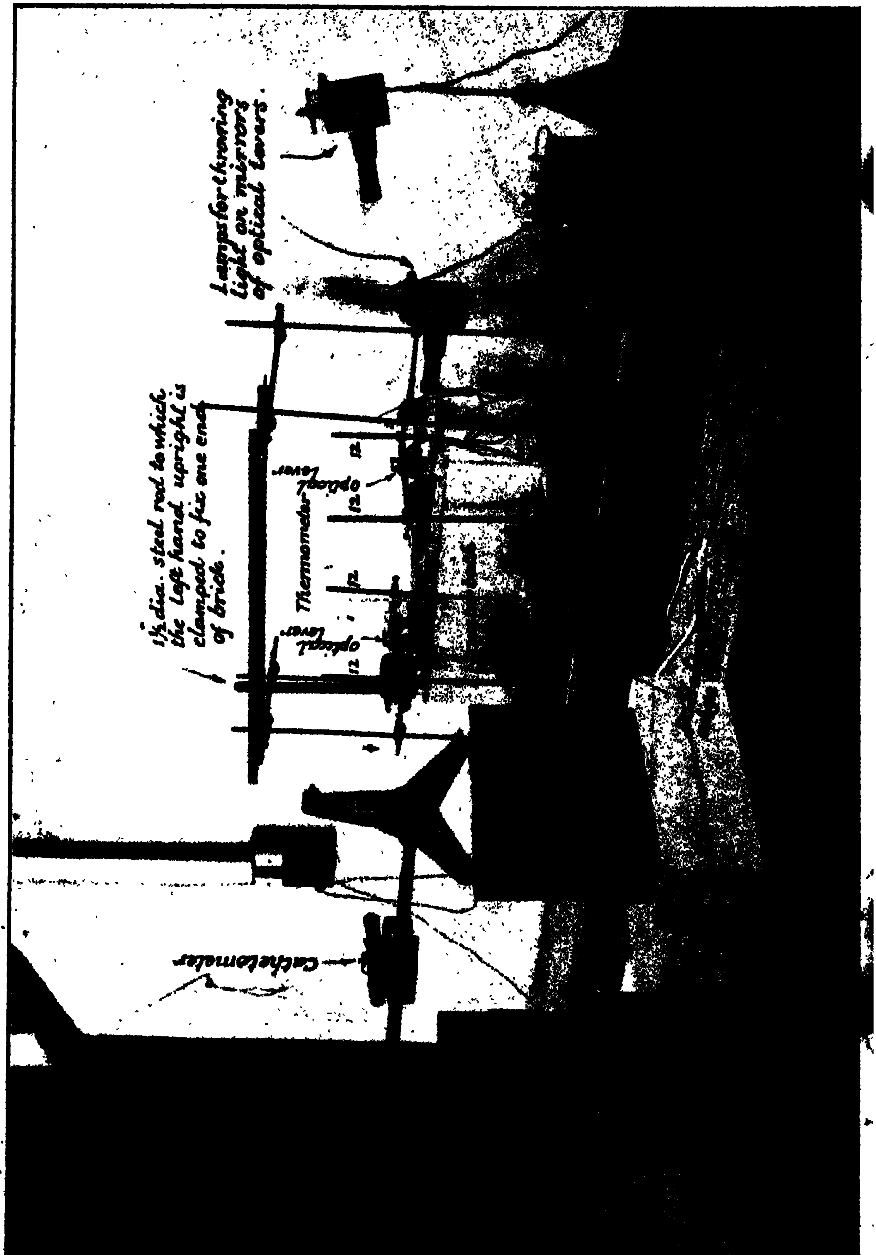

Lamps for throwing light on mirrors of optical levers.
1½ dia. steel rod to which the left hand upright is clamped to fix one end of brick.
Thermometer
optical lever
optical lever
Cathetometer

Photo. II.

DISCUSSION ON

TEMPERATURE STRESSES IN REINFORCED BRICKWORK AND THE FAILURE OF REINFORCED BRICKWORK ROOFS.

In introducing the Paper, Prof. Raja Ram said that the experiments which formed the basis of the subject of the paper were undertaken with the object of determining the effects of temperature variation on reinforced brickwork. The results of investigation were embodied in the paper and they spoke for themselves. He thought that it might perhaps be relevant to review briefly the present position of reinforced brickwork as a material for construction. Prof. Raja Ram.

For the sake of simplicity in design it was generally the practice to assume that reinforced brickwork construction was in all essential features the same as reinforced concrete construction save that "brickwork in cement mortar" was substituted for cement concrete. The principles of reinforcement also were assumed to be the same, and steel was used in various ways where necessary as in reinforced concrete, to give requisite strength to the material.

Mr. Brebner was the first engineer in India to conduct an experimental investigation into and to publish a book on this subject. All other engineers engaged in the design and construction of reinforced brickwork in India at the present day had generally accepted the fundamental principles laid down by Mr. Brebner in his publication. Therefore he thought it worth-while to quote the following information from Mr. Brebner's work. Mr. Brebner said that this form of construction was first introduced in the construction of the New Capital for Bihar and Orissa at Patna, and according to him proved so economical and successful from every point of view that the local Government decided to adopt it where possible. As a result of the recommendation of the Government of Bihar and Orissa to the Government of India, this form of construction was adopted by various other Governments.

There were six advantages claimed for it :—

(1) Simplicity of construction;

(2) Good, sound and permanent work involving very low repair charges;

(3) Fire-proof construction;

(4) Neat and artistic appearance of the finished work unlike that of jack arching or other systems in common use;

(5) Cool rooms;

(6) Low initial cost. It was claimed that it was cheaper than any other form of *pakka* roofing.

As regards the method of construction it was stated by Mr. Brebner that (a) each mason was given the dry mortar and he added water to it as he proceeded with his work, (b) the reinforcement was inserted as the work proceeded and experience showed that it was not nearly so liable to displacement as it was in reinforced concrete work and (c) there was nothing about the work which could deteriorate or require attention of any kind. The repair charges were therefore very low, in fact negligible, provided the brickwork was efficiently protected from weathering and damp by cement plaster or something similar.

WORKING STRENGTH OF MATERIALS AND THEIR SPECIFICATION.

A breaking stress of 1200 lbs/in^2 or over was said to indicate sufficiently good bricks. The safe working stress for bricks was taken equal to 250 to 350 lbs/in^2 in compression. The mortar generally used was 1 of cement to 3 of sand by volume. In some cases 1:2:4 concrete was used in place of 1:3 cement-sand mortar. Bond between steel and mortar was taken as 400 lbs/in^2 after 28 days.

Tests:—Tension and compression tests for brickwork were recommended. Temperature stresses were not investigated.

One of the recommendations of Mr. Brebner was that it was best to combine reinforced concrete work with reinforced brickwork in the construction of beams. As a rule the lower part of the beam in which the tensile reinforcement is placed should, according to Mr. Brebner, be constructed entirely of concrete though Military Engineering Services did not recommend that practice.

Having summarized the present-day practice Prof. Raja Ram said that they should consider it in its bearings on reinforced brickwork and reinforced concrete theory. It was necessary to examine closely whether the theory on which reinforced brickwork

design was based, was quite correct; the main points to be considered in this connexion were the following:— Prof. Raja Ram.

(1) If reinforced brickwork was theoretically treated as reinforced concrete work it might be specifically pointed out that instead of a mixture of $\frac{1}{2}''$ to $1\frac{1}{2}''$ stones, burnt mud bricks were used in reinforced brickwork. But if on this analogy $9'' \times 4\frac{1}{2}'' \times 3''$ size stone ballast instead of $\frac{1}{2}''$ to $1\frac{1}{2}''$ size were used in reinforced concrete, he doubted if any Engineer would consider it quite sound practice and if the resulting construction would have the same properties as the former. (2) Since the structure and strength of burnt mud bricks were on the face of it somewhat different from that of cement sand mortar or cement concrete it did not appear quite correct to assume that the two behaved as the one and the same or similarly without more comprehensive and definite tests in support of it. In fact an opinion might be hazarded in regard to reinforced brickwork that it was not made up of two such things as concrete and steel, but of three different things, namely, steel, cement sand mortar and bricks, the properties of the latter two being distinctly different in some respects. The bases for a part of this assertion were the observations made at Watford Building Research Station in regard to the deterioration of bricks. According to Dr. Strandling of Watford the most common cause of bad weathering properties of bricks was the crystallization of salts near the surface of bricks, the salts being obtained from the bricks themselves or the mortar, etc. According to the same authority a common cause of efflorescence in bricks in England was the absorption by bricks of the salts in the cement mortar, though lime mortar did not usually produce the same trouble. But in order to be definite whether the same effect was produced in bricks in India, further careful observations were necessary. The effect on the strength of reinforced brickwork due to this absorption of salts from cement mortar by bricks in reinforced brickwork if it did take place in India also needed investigation. Observations for this purpose might have to be made on reinforced brickwork not only after 28 days but also after the lapse of such long periods as two years or more.

Therefore owing to differing strength and other properties of bricks and cement-sand mortar the assumption that a plane section before bending remains plane after bending might not likely hold quite true in the case of reinforced brickwork.

Further so far as he was aware the elastic limit within which reinforced brickwork acted as a homogeneous material had not quite exactly been determined yet. Owing to the different strength

f. Raja m.

and different moduli of elasticity of bricks and 1:3 cement-sand mortar which made up the essential compression resisting component of reinforced brickwork it did not appear quite justifiable to apply the fundamental reinforced concrete formulae to reinforced brickwork, for instance, in the notation used by Taylor and Thompson—

$$(1)\quad \frac{E_s}{E_c} = n$$

$$(2)\quad \frac{\dfrac{f_s}{E_s}}{\dfrac{f_c}{E_c}} = \frac{d(1-k)}{kd} = \frac{1-k}{k}$$

$$(3)\quad K = \frac{1}{1 + \dfrac{f_s}{N f_c}}$$

$$(4)\quad f_s \times p \times b \times d = \tfrac{1}{2} f_c kdb$$

Considering the above formulae, it was definitely known that there was not one and the same value of f_c and E_c and therefore of n. for bricks and cement sand mortar.

Similarly other R. C. formulae might not hold good in the case of reinforced brickwork from theoretical considerations.

Lastly the co-efficients of expansion of cement-sand mortar, steel and bricks as shewn in the paper were different. Apparently therefore, reinforced brick slabs might develop cracks due to expansion and contraction after construction. What the size of these cracks was likely to be could only be guessed after sufficient data were supplied. In R. C. work the temperature and shrinkage cracks were distributed over the surface area as given on page 300 of Taylor and Thompson's Concrete, Plain and Reinforced Vol. I., but in R. B. work owing to the presence of large sized inert material, namely, bricks, the cracks were concentrated over the much smaller mortar surface, and therefore might be larger in size. Further, vibration might affect a R. B. roof more seriously than a R. C. roof on this account.

The rate at which heat was absorbed or conducted through a reinforced brick slab very likely depended to a considerable extent on the colour and the nature of the covering surface but the rate of its transmission from the upper side to the under side of a roof slab must vary in thick slabs in every horizontal section of it and produce interminate horizontal shear stresses. This also needed investigation.

Thus it appeared that perhaps a little undue liberty had been taken in using so extensively reinforced brickwork construction in India, without a fuller and more comprehensive investigation of the most fundamental properties of the materials that made up this composition. Large and important Government and public buildings which were intended to last for centuries if not millenniums like some of those at Oxford University now about 1,000 years old, should not have been built in reinforced brickwork without obtaining more data. For such a thorough investigation of this subject a properly trained engineer must have at his disposal not only a laboratory for testing strength and elasticity of materials but also chemical and physical laboratories with trained scientists in charge of them, as they had in Europe and in America. Prof. Raja Ram.

In conclusion he added that so far as he was aware R. B. had not been used for the construction of any important building in any European country until now, and this fact also might throw some doubt on the soundness of reinforced brickwork as a material for use in any important engineering construction.

Mr. Radha Lal said that the authors had given reasons with experiments for the failure of the works; and during the discussion Mr. Raja Ram admitted that R. B. roof slabs were cheaper than any other roofing (permanent of course). If cheapness and permanence were considered, it was not enough to give the causes of failure, but it was imperative to find out remedies (if any) to prevent the failures. In his experience of about 12 years he found that 3″ or 4″ good mud over the slab prevented heat of the sun affecting the slab. He hoped that Mr. Raja Ram would agree with him in the matter. It was a great problem and deserved solution. Mr. Radha Lal.

Mr. A. K. Datta said that he was associated with Mr. Brebner from the very beginning of reinforced brickwork (i.e., from 1916). He did all the experimental researches on reinforced brickwork and concrete at Patna under Mr. Brebner from 1916 to 1919. From 1919 to 1922, he was connected with Benares Hindu University Works. Thus he was in a position to describe the exact state of things both at Patna and at Benares Hindu University buildings. The appearance of cracks in R. B. roofs of some of the buildings at Patna was due to the lack of any cross rods in the slabs. No cross rods were used in these slabs at the beginning and most of the slabs were brick-flat and brick-on-edge. The cracks appeared along the length of the rods as there was nothing to prevent the appearance of cracks. That was a common thing in reinforced concrete slabs also without cross reinforcements or expansion joints. In Mr. A. K. Datta.

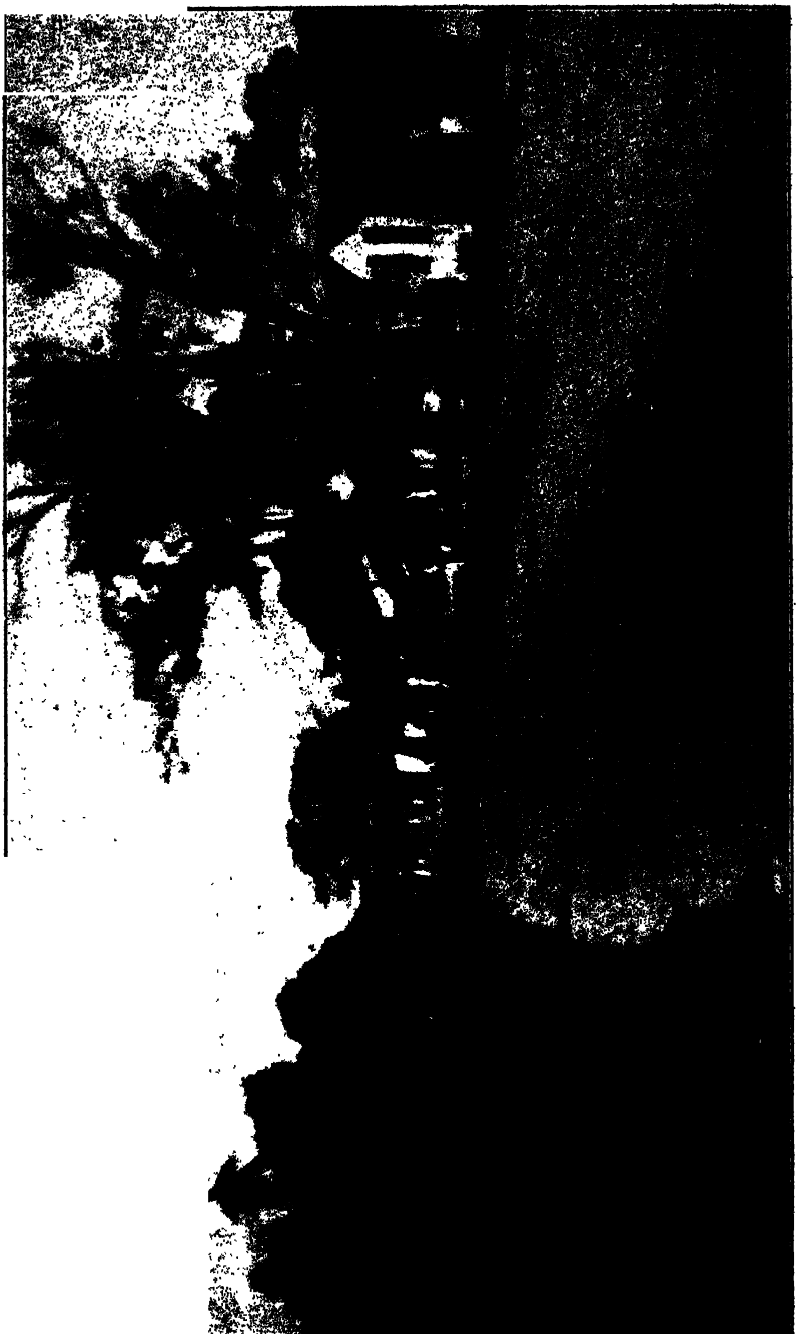
cases of R. B. roofs, where cross rods had been provided, there were practically no cracks in the roof slabs.

In the case of Benares Hindu University R. B. roofs, cross rods had been provided and such cracks did not appear. He had seen cases of R. B. roofs over verandah over 100 ft. in length where cracks had appeared. A crack often appeared at the junction two days' work, old and new, but that could be avoided by putting some extra cross rods one-half embedded in the first day's work and the other-half in the second day's work. He had constructed lacs of sq.ft. of both R. B. and R. B. C. slabs for roofs and floors in buildings but nowhere had a brick been reported to come down from the slab on account of temperature stress or other causes. The rates of expansion of concrete, steel, cement motar and bricks were similar and there was not much difference. 6" Brick Concrete Roads, both plain and reinforced, were constructed in April, 1932 at Calcutta—Jessore Road, 5th mile and the photograph of the same, (vide page 121), was taken in January 1934, i.e. after 20 months of use. On examining the photograph carefully, it would be clearly seen that no cracks had developed in any part of the road slabs. In spite of the fact that the slab had been exposed to the sun and rain and also to heavy traffic for all these months, the bricks, concrete and steel had all worked together as one mass and they had not separated anywhere. The expansion joints had been provided at every 30 ft. The drawing (inserted after page 121) showed the sections of those brick concrete roads, both plain and reinforced. There was a half-inch layer of sand below to allow free expansion of the slabs. In the case of concrete roads also, cracks would appear unless proper expansion joints were provided therein. In the cases of Central Avenue Concrete Road of Calcutta, 5" bottom concrete was with 1 :2 :4 and the top 2" with 1 :1 :2, reinforced at bottom with No. 9 B. R. C. fabric and at top with No. 14 B. R. C. fabric; no expansion joints were provided in the same with the hope that the slab would not crack. Now if anybody examined the surface he would find cracks, practically at every 30 ft. extending throughout the whole width of the slab. In the subsequent construction of concrete roads, expansion joints had been provided at every 30ft. and no cracks had appeared in these roads. Mr. Raja Ram had tried to prove by experiments that the co-efficient of expansion of brick was very much greater than that of cement mortar or concrete or of steel.

For brick—0.0000083 per degree of Fah.

For 3 :1 cement mortar (concrete)—0.0000056 per degree of Fah.

For iron bar—0.000006 per degree of Fah.



R B. C. & B. B. C.

April 1932.
Photo. ken—8th January 1934.

The result for bricks appeared to be absurd for the simple fact that brickwork in cement was in use for many years and nowhere had the bricks been found to be separated from the mortar. Thus actual fact did not support the conclusion of Mr. Raja Ram's experiments. Had there been different rates of expansion between bricks and cement mortar the whole brickwork would have been crumbled to separate bricks and mortar but that never happened. In American Civil Engineer's Pocket Book, the co-efficient of expansion for brick was given as practically equal to that of cement concrete or of steel (vide page 288 2nd Edition).

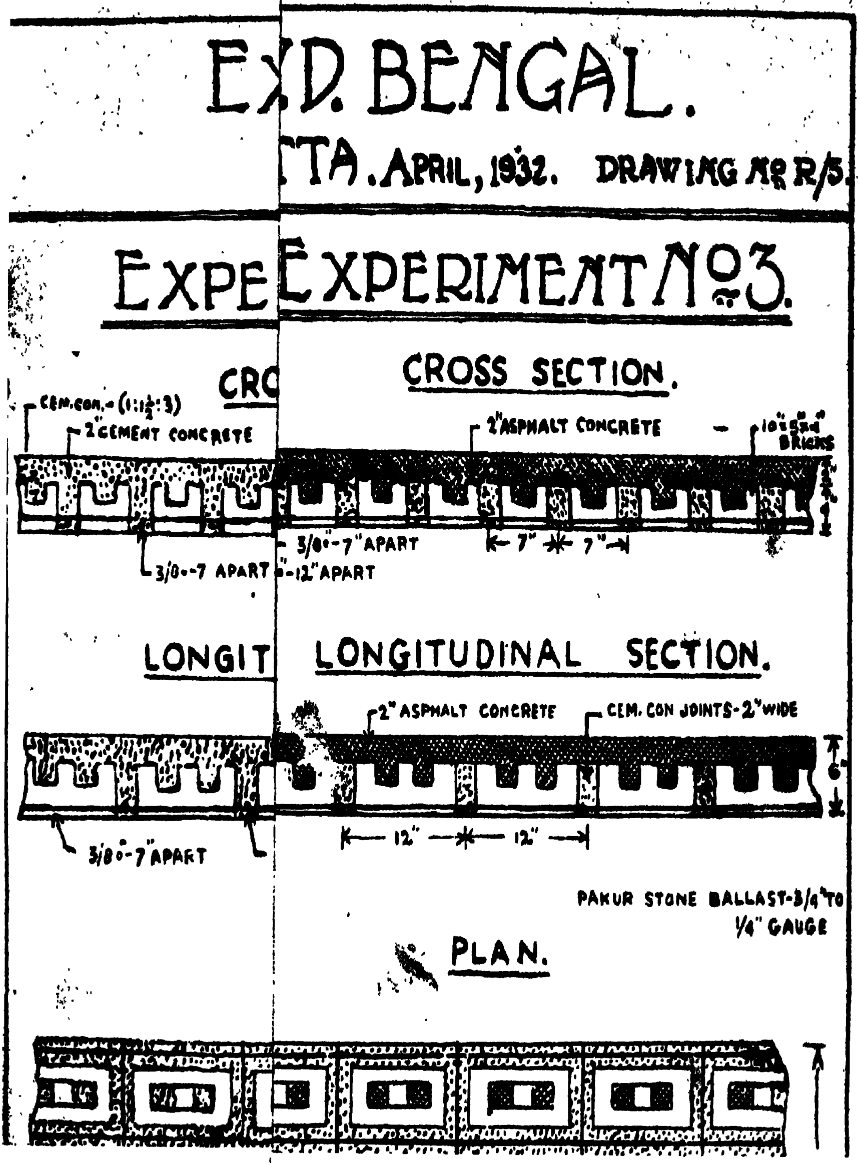
Co efficient of expansion of

cement concrete—per degree of Fah.—0.0000055

Ditto	Ditto of steel-	Do.	—0.0000065
Ditto	Ditto of brick-	Do.	—0.0000050

whereas the co-efficient of expansion for bri[illegible] as found by Mr. Raja Ram was 0.0000083; so, that appeared to be wrong. For roofs and floors of numerous buildings, he had constructed 4" R. B. C. slabs. They consisted of 3" brick with 1" cement concrete on top with 1½" to 2" joints of cement concrete with the reinforcing rods in the lower part. In these slabs he did not find any crack developing between the bricks and the concrete or steel. The bricks, concrete and the rods all when set, worked as one mass. If very long slabs were constructed without expansion joints or cover on top, cracks would appear at intervals of 25ft. or so but that was also the case with the reinforced concrete slabs.

The development that had been done now in reinforced brickwork was in the domain of protection of rods from corrosion by using wide concrete joints, 1½" to 2½" wide (usually) with a layer of cement mortar up to top of the rods. In his opinion, reinforced concrete (R.C.), reinforced brickwork (R.B.), reinforced brick concrete (R.B.C.), when properly constructed would produce safe construction and if they were not properly done, the construction would be defective in all cases.



E.D. BENGAL.
TTA. APRIL, 1932. DRAWING No R/5.
EXPERIMENT No 3.
CROSS SECTION.
CEM. CON. (1:1½:3)
2" CEMENT CONCRETE
2" ASPHALT CONCRETE
10"×5"×3" BRICKS
3/8"⌀-7" APART
7"
7"
12" APART
LONGITUDINAL SECTION.
2" ASPHALT CONCRETE
CEM. CON JOINTS-2" WIDE
6"
12"
12"
3/8"⌀-7" APART
PAKUR STONE BALLAST-3/4" TO 1/4" GAUGE
PLAN.

Mr. D. R. Jain asked how many samples of bricks were tested by the authors before the new co-efficient of expansion of Roorkee bricks was arrived at. Mr. D. R. Jain.

Mr. K. L. Jain remarked that with regard to each design the following points should be considered :— Mr. K. L. Jain.

(1) Feasibility of production as regards material labour and process of manufacture.

(2) Capacity of workshop to carry out the work with the tools and appliances available.

(3) Construction of patterns and moulds with adaptability for rapid production.

(4) Degree of standardization possible and advisable especially with regard to details.

(5) Possible economy in selection of materials.

(6) Total cost of production with available plant with possible diminution if special machines provided.

The existing reinforced brickwork roofs of the Benares Hindu University Buildings were so far as he knew working satisfactorily and considering the cost he was of opinion that the roofs of reinforced brickwork should not be entirely rejected. Considering economy and other points for selecting a particular design mentioned already, reinforced brickwork roofs should be adopted.

Rai Saheb K. C. Banerjee said that the subject of Professor Raja Ram and Mr. Ananda Saroop's paper was of considerable interest to Bengal engineers generally and to him in particular for the reason that reinforced brickwork was still largely used in Calcutta and elsewhere in Bengal, and engineers like himself were responsible for the design and construction of many floors and roofs of reinforced brick. Fortunately, however, where such slabs were covered with a layer of lime concrete or patent stone he did not experience any difficulty due to temperature variations. Before going to Delhi, he visited some of these structures, which were 5 or 6 years old, and found them free from any crack and they sustained the earthquake shock without any trouble. The cracks might appear owing to causes other than variations in atmospheric temperature, they might be due to water cement ratio of the mortar, the manner of curing, the soundness of the cement, etc. With regard to temperature stresses the data so far available were foreign Rai Sab K. C. Banerjee

and he was grateful to the authors for the experiment which was probably first of its kind in this country. The co-efficient of expansion of brick given by various authorities varied from .0000031 to .0000038 per degree Fahrenheit, but the authors had found it to be .0000083 for Roorkee bricks. He did not know if the authors had investigated the cause of difference. The co-efficient of expansion for steel was about the same as found by other authorities. That stresses were developed owing to temperature variation was a well-accepted fact, but the moot point was what variation was to be provided for in the evaluation of stresses in designing a structure. Information on this point was meagre and the opinion varied considerably. In England where the atmospheric variation was taken to be 50°F., the temperature variation allowed in calculation was assumed to be +30°F., whereas in America it was taken to be +40°F. It was reported that diurnal variation of temperature had little effect on concrete, and the yearly range of 24 hours mean temperature had considerable effect. The internal variation of temperature in concrete or other structure was only responsible for its deformation, and therefore, all calculations for temperature stresses should be based on this variation. On this point, however, very few investigations had been made. He wished that the authors would continue their experiments further and try to find out the relation between the atmospheric range and the range of internal variation. So far as he was aware two experiments were made—one by the University of Illinois and the other by Iowa State College of Agriculture. The latter experiments showed internal variations to be 75% of the atmospheric variations in mass concrete of 5 to 6 feet in depth; the usual practice in America, however, was to take half the atmospheric variation. The range of internal variation would vary considerably according to the position of the structure, the temperature of the atmosphere in which the work was done and also its thickness. He thought it would be sufficient if provision were made for the greater of the two ranges of variations above or below the temperature of no stress of steel, which would be different in different structures. So he thought the authors' evaluation of temperature stresses as given in the paper might not be correct.

Mr. T. S. Jotwani said that it was very interesting to go through the results of the Authors' experiments which indicated that some of the failures in reinforced brickwork roofs might be partly due to different co-efficients of expansion of bricks and the cement mortar. He personally differed from the conclusion arrived at by the authors that in most cases the failure of reinforced brickwork could be traced to the stresses caused by temperature

variation and the difference in co-efficients of expansion of the materials used. This form of construction had not always proved successful mainly due to corrosion of the reinforcing rods. Most of the failures in R. Brick roofs had been noticed after a number of years and on careful inspection of such roofs it was found that the sectional area of the reinforcement had gradually diminished because of corrosion till the point had been reached when the roof slab was weak in tension and consequently cracked. If the failure was mainly due to the difference in co-efficients of expansion of the materials used it should have very likely occurred in the course of a year after the slab had been subjected to maximum ranges of temperatures during the worst part of the first year. This type of roof showed economy over other forms of construction in districts where bricks were good and cheap, also where suitable aggregates for ordinary concrete were not available; there were many such districts in India. The only care required was to prevent the corrosion of the reinforcement. Bricks contained corrosive elements with the result that in some places, where the reinforcement was in direct contact with bricks in the reinforced brickwork, it got seriously corroded and even completely eaten through at various points. It was not necessary that the reinforcement should be corroded throughout its entire length for a failure to occur. The strength of a chain is the strength of its weakest link, and if the reinforcement is reduced in area by corrosion at any point on its length, the value of the reinforcement must be only that of the reduced area of section at the point of corrosion. The corrosion of the steel bars might partly be due to the cement mortar being porous. He was, therefore, of the opinion that there should be no failures of R. Brickwork roofs provided the workmanship was good, the joints between bricks were of such a width that there would be at least $\frac{3}{4}''$ clearance between the side of the rod and the brickwork and the cement sand mortar in the joints was in proportions of 1 :2. Mr. T. S. Jotwani.

Mr. R. K. Sarkar said that according to Professor Raja Ram, the co-efficient of expansion of brick and cement mortar were different and as such bricks and cement mortar should not work together as one mass, under heat. In the case of a big brick chimney constructed in the Lucknow Water Works under the supervision of the Public Health Department cracks had appeared vertically as well as horizontally in the cement-brick part. The chimney which was circular and about 175 ft. high had cracked in four places vertically on four sides and the cracks while over 1 inch in some places had not followed the cement joints but had traversed the bricks coming in the line of the cracks. This clearly showed that the bricks and the Mr. R. K. Sarkar.

cement mortar worked together under high temperature. Had the co-efficient of expansion been different they would have cracked through the joints of the brick in all directions. It might be interesting, however, to note that no crack had appeared in the upper part of the chimney which was of *kunker* lime mortar.

Mr. M. Z. Faruqi said that Mr. Raja Ram advocated the use of reinforced brick with great caution on the ground that the factors which actually came into play were not identical with the cement concrete. This might be true, but it remained to be ascertained to what extent they differed. As an engineer, the practical results were to him equally important as the theoretical calculations; and these theoretical calculations helped in the first instance to arrive at certain dimensions of the slabs, etc., which could be expected to safely support a certain load and resist the stresses produced. Cement brickwork was being used extensively but it did not necessarily follow that the work that was being done was based on the calculations, and that the actual construction was being carried out on scientific lines according to specifications. It was of the greatest importance that an engineer should guard against the mistaken ideas of construction, and it seemed necessary to mention that the failure of reinforced brickworks was due to faulty construction and most probably not to mistakes in the assumptions for calculations. These mistakes could be classed as under:—

(i) the joint between the bricks was too thin to allow the mortar filling in fully between the bricks with the natural result that the mortar in between the bricks was left in a spongy shape and harboured moisture besides being weak and not offering sufficient adhesion;

(ii) the mortar did not cover the steel reinforcements in the joints and the expected adhesion never came into play. The steel rods did not adhere to the mortar; even 50 per cent of its surface was left untouched by cement mortar;

(iii) Sometimes the mortar was too stiff and did not run round the reinforcement, and at others it was much too sloppy and its resulting strength was very much reduced, and air bubbles remained inside the mortar and many of them on the surface of the steel;

(iv) The position of the reinforcement which was calculated with great accuracy at the time of design was practically lost sight of at the time of construction and the metal was not kept where it was intended and thus the strength was materially reduced;

(v) The centring in the case of R.B. slab was to be stronger than Jack arch roof but this was lost sight of; and the centring kept giving way and disturbing;

(vi) The mortar used was often not water-tight even in the case of roofs. It was admitted that 1 :3 cement mortar was not water-tight, and for roof work it was imperative that it ought to be 1 :2. The 1 :2 mortar was preferable for floor work also. Mr. M. Z Faruqi.

The engineer of to-day had to use his influence where possible towards the right use of this material. The public were blindly using the R. B. for roofs and floors and they might come to grief for not attending to the specifications. These failures might be used as an argument against R. B. roof construction though the engineers who had used this type of roof knew the points in favour of Reinforced Brick Construction so well.

Professor Raja Ram, in reply to the points raised by the various speakers, said that he had noted Mr. Radha Lal's remarks and pointed out that before any remedy was suggested the causes of a failure must be definitely ascertained. Within the brief periods snatched from their busy official life he and Mr. A. Saroop had investigated as far as they could, though not quite comprehensively, some of the causes of the failures of R. B. roofs. He agreed with Mr. Radha Lal that it was necessary to find the remedies, if there were any, to prevent failures and said that it was a recognized fact that mud covering was a bad conductor of heat and if it was painted white with lime it absorbed still less heat of the sun and kept the roofs cooler. The Aut

Regarding Mr. A. K. Datta's comment that the failure of roof slabs at Patna was due to the non-provision of cross bars, he pointed out that cross bars, as engineers were well aware, were generally used to prevent temperature and shrinkage cracks. This evidently supported the view propounded by the authors in the paper. As regards cracks along the length of the bars, he pointed out that in R. C. work owing to the nature of that material the bars could be properly spaced and therefore the cracks were fine and were termed hair cracks and were closely and evenly distributed, but in R. B. work owing to the large size of bricks these were not and could not be evenly and closely distributed. Regarding non-appearance of cracks in R. B. roofs in which cross bars had been provided, he suggested that one should wait and see before one could pass any final verdict : regarding R. B. roofs of over 100′ in length over verandahs, Mr. Datta had said that he had seen no cracks in them yet. Prof. Raja Ram considered that it was better to divide up 100′ long slabs into about 10 to 20′ lengths each and provide expansion joints in between. He suggested that Mr. Datta should in this case also wait and see before pronouncing his final

uthor. opinion on jointless slabs of over 100′ length. He did not dispute the statement of Mr. Datta regarding the bricks dropping out of roof slabs constructed by him, but the fact that such a thing had happened in a famous building in India and had been reported in the press all over India could not be discounted. He did not agree with Mr. Datta's statement that the rates of expansion (by which he understood Mr. Datta to mean the co-efficients of expansion) of concrete, steel, cement mortar and bricks were similar and not much different. The remarks of Mr. Datta regarding R. B. roads, though interesting, did not in the opinion of Prof. Raja Ram affect the R. B. roof slabs and therefore the facts quoted by Mr. Datta did not call for any special notice. Regarding the remarks about the absurdity of the results obtained by the authors, Prof. Rajr Ram said that Mr. Datta could not help accepting the two values of the co-efficients of expansion of steel and concrete simply because they agreed with those given in numerous books, but Mr. Datta seemed to believe that the value of the co-efficient of expansion of bricks found by the authors by means of the same apparatus and under the same conditions was wrong simply because it did not tally with the value given on page 288 of the American Civil Engineers Pocket Book, 2nd Edition. He pointed out that bricks are not made of the same kind of clay all the world over, that there is no such thing as a universal standard clay or brick in India and that the co-efficients of expansion of bricks of different kinds of clay burnt possibly under different conditions and perhaps at different temperatures must necessarily be different.

In reply to Mr. D. R. Jain's question he said that the bricks were obtained from five different Kilns in Roorkee and that about 10 to 12 samples were tested, each sample being tested several times.

Mr. K. L. Jain's views that further investigations on the subject were desirable were shared by Prof. Raja Ram.

In reply to Rai Sahib K. C. Banerjee, Prof. Raja Ram said that the Rai Sahib like Mr. Datta attached a somewhat exaggerated sanctity to the value of the co-efficients of expansion of bricks given in the various books and referred the Rai Sahib to the reply be had already given on this point in dealing with Mr. Datta's comments. He agreed that the difference between atmospheric and internal variation of temperature in brickwork needed fuller investigation. This depended upon several factors—the material of the bricks, the

colour of the bricks, the humidity, etc. etc., besides the range of atmospheric temperature. He did not agree that his and Mr. A. Saroop's calculation of temperature stresses was incorrect but he considered that what Mr. Banerjee meant was perhaps that the conditions for the calculations might be different. The Autho

With regard to Mr. Jotwani's remarks he said that Mr. Jotwani considered that even some of the failures of R. B. work were not due to differences in the co efficients of expansion of its constituent materials for he found that cracks appeared long after construction and that if they were due to different co efficients of expansions they should appear in the course of a year after its construction. Prof. Raja Ram did not doubt that some cracks might be due to corrosion of steel. He, however, pointed out that repetition and reversal of stresses due to temperature variations might not and did not reach the cracking limit in a year or so. He was of the opinion that besides the three points mentioned by Mr. Jotwani which would prevent failures in R. B roofs there were several others that must be taken into account such as temperature and shrinkage, reinforcement, water cement ratio, quality of bricks, soaking of bricks in water, etc., etc.

In reply to Mr. Sarkar's remarks that since cracks appeared in the bricks and not in the cement mortar between the bricks of a chimney constructed at Lucknow, the co efficient of expansion of bricks and cement mortar could not be different, Prof Raja Ram pointed out that according to the results obtained at the Watford Building Research Station bricks absorbed some salts from cement mortar but did not do so in the case of lime mortar. Therefore, it was not surprising if no cracks appeared in brickwork in lime, more especially because good lime mortar and bricks had been known for centuries to behave as a monolithic and homogeneous material under ordinary atmospheric temperatures. In the case of brickwork in cement mortar the failure was evidently due to the fact that adhesion between brickwork and cement was greater than the tensile strength of bricks at higher temperatures such as those usually obtained inside a chimney.

Regarding the points raised by Mr. Faruqi, Prof. Raja Ram agreed with him so far as he detailed some of the causes of failures in R. B. work.

Prof. Raja Ram said in conclusion that if progress were to be made in engineering construction the properties and strength of the materials used must be known as exactly as possible and

The Author. therefore for proper design and construction of R. B. work a more comprehensive and exact knowledge of its constituent materials was desirable. He added that theory was the rationalised essence of practice and if at any time or in any instance theory did not support practice, it needed readjustment and this was what was being done every day by scientific investigators. Engineers could not afford to work for ever with empirical methods and rules when the means of correct experimental determination were readily available to them throughout the civilized world.

THE ECONOMIC DIMENSIONS OF REINFORCED CONCRETE RESERVOIRS

BY

GEORGE BRANSBY WILLIAMS, Member.

In this paper a method is described of arriving at the most economical dimensions of two types of open reinforced concrete reservoirs: Type A.—reservoirs in which the thrust produced by the water pressure is assumed to be resisted entirely by the tension on the horizontal reinforcement in the walls; and, Type B.—reservoirs with walls designed as retaining walls. The present investigation is confined to uncovered reservoirs, because the mathematical treatment of the problem is made more complicated in covered reservoirs by the modification of the stresses in the walls caused by their attachment to the roof. Only circular reservoirs need be considered. Reservoirs of Type A. must obviously be circular in plan, and, as the shortest line bounding a given area is a circle, the cheapest reservoir of Type B. for any given depth must also be a circular one. Where it is necessary to construct reservoirs and tanks rectangular in plan, or of any irregular shape, to fit in with the rest of the works, their dimensions will be decided by considerations which will preclude their being arrived at by any general mathematical formulæ.

To simplify the investigation, certain assumptions are made, which, although not strictly correct, do not entail sufficient inaccuracy to affect materially the comparative results. For the mathematical calculations, the volume of concrete in the shells of any reservoir is taken to be the sum of the products of the areas of the interior wetted surfaces and the average thickness of the shell behind the respective areas. The possibility of outside earth pressures on the walls is disregarded. When the economic dimensions have been arrived at mathematically, the estimated volume of concrete in a reservoir of any given capacity is obtained, as far as possible, by accurate mensuration.

RESERVOIRS TYPE A. (WALLS WHOLLY IN TENSION).

In a reservoir of this type the reinforcing steel is designed to take the whole of the bursting stress on the wall produced by the pressure of the water. The surrounding concrete must obviously be

stressed also, and, although this stress is not taken into consideration in calculating the strength of the structure, it must be restricted to an intensity that will not cause cracks in the wall and consequent leakage. This intensity is assumed herein to be an average throughout the wall of 175 lbs. per square inch. The limit of the working stress on the steel is taken as 12,000 lbs. per square inch. Consider a cross-sectional area of 100 square inches of concrete reinforced with p square inches of steel. Then for the purpose of calculating the effective stress on the concrete, the composite structure of steel and concrete may be looked upon as equivalent to an area of 100 + p(m -1) square inches of concrete, m being the ratio of the moduli of elasticity $\frac{Es}{Ec}$. If m is taken as 12, T the total tensile stress on the cross section of the wall, and t_c the allowable stress on the concrete, then;

$$T = (100 + 11p) \times t_c$$
$$= (100 + 11p) \times 175$$

As this is assumed to be wholly taken by the steel reinforcement

$$T = p \times 12000$$
$$\therefore\ p \times 12000 = 17500 + 1925\,p$$
$$\text{Whence} \quad p = 1.737 \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

This is the area of steel in 100 inches of concrete, so the percentage of reinforcement is 1.737, which may be taken as the theoretically correct percentage at all points in any reservoir wall wholly in tension.

The tension on 100 square inches of reinforced concrete on the basis of the allowable stress on the concrete is

$$T_c = 175\ (100 + 11 \times 1.737) = 20{,}844 \text{ lbs.}$$

or, alternatively, on the basis of the allowable stress on the steel,

$$T_s = 12000 \times 1.737 \text{ which also} = 20{,}844 \text{ lbs.}$$

The tension on one square foot of concrete is thus

$$\tfrac{144}{100} \times 20{,}844 = 30{,}015 \text{ lbs.}$$

In this investigation it is assumed that the reinforcement in the walls is sufficient to withstand the whole of the stress produced by the water pressure. Actually the stress at the bottom of the wall does not all come upon the horizontal reinforcement, owing to the wall being anchored to the floor. This fact is disregarded for present purposes, and, as a basis for the calculations, it is assumed that in any wall in this class of reservoir, the average thickness of the wall is the average tensile stress on it in pounds per sq. foot ÷ 30,000.

Any reservoir containing h feet of water the maximum intensity of pressure at the bottom of the wall is hw lbs. per sq. foot, w being the weight of a cubic foot of water. The average pressure on a vertical strip of wall 1 foot wide is therefore $\frac{wh}{2}$ lbs. per sq. foot and the total pressure on the strip is $\frac{wh^2r}{2}$

In a circular reservoir with a diameter = 2r feet the average bursting pressure per vertical foot of wall produced by the water is therefore $\frac{wh^2r}{2h} = \frac{whr}{2}$ lbs. If d is the average thickness of the wall then ex hypothesi

$$d = \frac{whr}{2 \times 30{,}000}$$

and, if w be taken as 62.5 lbs.,

$$d = 0.00104hr \text{ feet} \qquad (2)$$

In comparing the costs of different types of reinforced concrete reservoirs it is necessary to allow for the variation in the cost of the concrete with the amount of reinforcement and the nature of the falsework. For this purpose the cost of plain unreinforced concrete, *e.g.*, in an unreinforced floor, is taken as a standard, and the volume of all reinforced concrete is increased to an equivalent volume of this unreinforced concrete. It is assumed that the concrete is composed of 1 part cement to 2 of sand and 4 of stone. It is found that on an average the cost of the falsework in the walls, including fixing, and the extra cost of getting the concrete into position behind this falsework, is approximately equal to the cost of the unreinforced concrete, and that the cost of 1 square inch of reinforcement in a block of concrete 1 foot long is equivalent to 1/3rd cubic foot of unreinforced concrete.

The cost of 1 cubic foot of concrete in a reservoir wall reinforced with 1.737% of steel is therefore equivalent to the following quantity of unreinforced concrete:—

1 cub. ft. of concrete is equivalent to			1.00 cubic foot
falsework		,,	1.00 ,,
1.737 × 1.44 sq. inches of reinforcement			
is equivalent to	$\frac{2.50}{3}$	=	.83 ,,
		Total	2.83 cubic feet

Thus a reinforced wall d feet thick may be considered equivalent in cost to an unreinforced wall d × 2.83 feet thick and the average thickness from equation (2) becomes an average equivalent thickness

$$D = .00104 \times 2.83hr \text{ feet}$$
$$= .00294 \times hr \text{ feet} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

In this paper the volume and thickness of unreinforced concrete equal in cost to any given volume and thickness of reinforced concrete are referred to as the "equivalent" volume and thickness of the latter.

It is assumed that the floor of the reservoir is composed of concrete 7 inches thick reinforced with ½% of steel and resting on a suitable foundation of brickwork or lime concrete. The equivalent volume of 1 square foot of floor will be

concrete		.583 cubic feet
reinforcement		.140 ,,
	Total	.723 ,,

To this must be added the cost of the excavation and the foundation masonry, which will vary considerably, but which may, for present purposes be taken as equivalent to .277 cubic feet per square foot of floor surface. Thus the concrete in the floor, including reinforcement, excavation, est., may be considered equivalent to an unreinforced floor 1 foot thick.

As has been previously stated, in considering the comparative anatomy of the reservoirs, the volume of concrete in the shell is assumed to be the areas of the wetted surfaces multiplied by the thickness of shell behind them. If d_1 and d_2 are the average thicknesses of the walls and floor respectively, the volume of reinforced concrete is

$$v \cdot 2\pi rhd_1 + \pi r^2 d_2 \text{ cubic feet} \quad (4)$$

If D_1 and D_2 are the equivalent thicknesses of unreinforced concrete the equivalent volume is

$$V = 2\pi rhD_1 + \pi r^2 D_2$$
$$= 2\pi hr \times .00294\ hr + \pi r^2 \times 1.00$$
$$= .00588\pi h^2r^2 + \pi r^2 \text{ cubic feet} \quad (5)$$

If C is the capacity of the reservoir in cubic feet

$$C = \pi r^2 h \qquad \sqrt{\frac{C}{\pi h}} \text{ and (5) becomes}$$

$$V = .00588\,Ch + \frac{C}{h} \qquad (6)$$

In the most economical reservoir of capacity C, $\frac{dV}{dh}$ must $= 0$

$$\therefore \quad .00588C - \frac{Cr}{h} = 0 \quad \ldots \quad \ldots \quad (7)$$

$$h^2 = \frac{1}{.00588}$$

$$h = 13.041 \text{ feet} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

From this it appears that for uncovered reinforced concrete circular reservoirs with the walls in tension, the average thickness of the walls being in proportion to the average tensile stresses, the theoretical economic depth is a constant for all capacities. In the conditions assumed this depth is 13.041 feet, which for practical purposes may be taken as 13 feet.

With this depth of water the average thickness of the reinforced wall is

$$d_1 \quad .00104 \quad 13r \text{ feet}$$

or in terms of C

$$d_1 \quad .00212\sqrt{C} \text{ feet} \qquad (9)$$

From a practical point of view there is a limit to the thickness of a reinforced concrete wall below which construction becomes difficult.

Assuming, in the cases under consideration, that the thinnest wall that can be properly constructed will have an average thickness of 6 inches, and substituting .5 for d in equation (9) it appears that the lowest value of C for which this equation will hold good will be

$$C = \frac{}{.00212}$$

$$= 55{,}858 \text{ cubic feet} \qquad (10)$$

Reservoirs of smaller capacity will have walls 6 inches thick, the area of the reinforcement being reduced to that required to withstand the tension produced. It has been found that in these conditions the economic depth of a reservoir with a capacity of 10,000 cubic feet is approximately 12 feet, and with a capacity of 25,000 cubic feet 12.5 feet.

Table 1 shews the economic dimensions of uncovered reinforced concrete reservoirs of type A. from 10,000 cubic feet to

500,000 cubic feet capacity, the equivalent volume of concrete in the shell, and the equivalent volume per 1,000 cubic feet capacity of the reservoir, derived from the foregoing conclusions.

TABLE 1.

ECONOMIC DIMENSIONS AND EQUIVALENT VOLUMES OF CONCRETE IN UNCOVERED REINFORCED CONCRETE RESERVOIRS TYPE A. WALLS WHOLLY IN TENSION.

Capacity of reservoir.	Economic depth of water.	Economic diameter.	Average thickness of wall.	Equivalent average thickness of wall.	Equivalent volume in reservoir shell.	Equivalent volume per 1000 cu. ft. capacity.
Cu. feet.	feet.	feet.	feet.	feet.	Cu. feet.	Cu. feet.
1	2	3	4	5	6	7
10,000	12	32·62	·50	1·16	2,500	250
25,000	12·5	50·45	·50	1·28	5,100	205
50,000	13·0	69·98	·50	1·40	8,600	172
75,000		85·70	·58	1·64	12,600	168
100,000		98·94	·67	1·89	16,800	,,
150,000		121·20	·82	2·32	25,200	,,
200,000		139·94	·95	2·68	33,600	,,
300,000		171·40	1·16	3·28	50,400	,,
400,000		197·92	1·34	3·79	67,200	,,
500,000		221·34	1·49	4·24	84,000	,,

In calculating the volumes in column 6 it has been assumed that the top of the walls of the reservoir is, in all cases, 9 inches above the top water level. The volumes exceed by nearly 10% those that would be obtained from equation (6). As Previously explained this discrepancy does not materially affect the accuracy of the investigation. It is to be observed that in this class of reservoir the equivalent volume per 1,000 cubic feet capacity is a constant=168, for all capacities above 56,000 cubic feet.

RESERVOIRS TYPE B. WALLS DESIGNED AS RETAINING WALLS.

In this type of reservoir the pressure of water on the wall is considered to be resisted by the latter acting as a retaining wall anchored at the base. Reinforced concrete retaining walls may be either (a) plain walls or (b) walls with buttresses and reinforced panels between. The latter type is more economical for high walls, but for walls of the height dealt with in this paper type (a) is cheaper and only this type need be considered. The wall

may either be reinforced near the inner face against tension only, or near the outer face against compression also. In the latter form of design the thickness of the wall can be reduced, but it will be found that the cost of the additional reinforcement required exceeds the saving effected in the concrete. For example. A wall capable of withstanding the pressure of a 10 feet depth of water, if reinforced on the inner side against tension only, would be 12 inches wide at the base, and the average equivalent thickness would be 1.5 feet. If reinforced with 2% of steel against tension the corresponding reinforcement required against compression would be 3%. In this case the width of the wall at the base would be reduced to 9 inches, but the equivalent average thickness would be increased to 1.7 feet.

For the purpose of this investigation, only walls reinforced against tension on the inner face need be considered.

In Fig. 1 the resultant pressure of the water on a strip of wall 1 foot wide, above any plane a b is wH where H is the depth of water above a b in feet and w the weight of a cubic foot of water. This resultant acts at a point $\frac{H_1}{3}$ feet above a b and the bending moment around b is $\frac{wH_1^2}{2} \times \frac{H_1}{3} = \frac{wH_1^2}{6}$ foot pounds. Taking w = 62.5 lbs. the bending moment on a plane a b, 12 inches wide is $M = 125H_1^3$ inch lbs.
H_1 being in feet.

The bending moment at the bottom of the wall is 125 H inch lbs. The bending moment at any plane is to be withstood by the moment of resistance of the steel and concrete.

Fig. 2 (a) represents a strip of the reservoir wall 12 inches wide. Fig. 2 (b) is the diagram of the stresses produced on the plane a a, b b, by the action of the water pressure P.

If p = steel ratio = $\dfrac{\text{area of reinforcement in sq. inches}}{12 \times d_s}$

f_s = tensile stress on the steel

f_c = compressive stress on concrete

d = distance of reinforcement from outer face in inches.

Then the moment of resistance considered in terms of the steel reinforcement is

$$M_s = p \times 12d \times f_s \times jd$$
$$= 12pf_s jd^2 \qquad \ldots \qquad \ldots \qquad (12)$$

In terms of the concrete it is

$$M_c = \frac{f_c}{2} \times kd \times 12 \times jd$$
$$+ 6\ jkd^2\ f_c \qquad \ldots \qquad \ldots \qquad (13)$$

As M_s and M_c must be equal

$$12pf_s\ jd^2 = 6\ jkd^2\ f_c \qquad \ldots \qquad \ldots \qquad (14)$$

Taking f_s at 120000, f_c as 600 and k as ·375

$$p = \cdot 00934 \qquad \ldots \qquad \ldots \qquad (15)$$

From the diagram it will be seen that

$$J = 1 - \tfrac{1}{3}k$$
$$= \cdot 875 \qquad \ldots \qquad (16)$$

The moments become

$$M_s = M_c = 1180\ d^2 \qquad \ldots \qquad \ldots \qquad (17)$$

from (11)

$$1180\ d^2 = 125\ H^3$$

$$\cdot 325 \sqrt{H^3} \qquad \ldots \qquad \ldots \qquad \ldots \qquad (18)$$

It will be seen from (15) that the theoretical steel ratio is .00931 at every point in the wall and for all depths of water. For the purposes of this investigation it is assumed that the average percentage of reinforcement for all walls of this type is 1.0.

In Fig. 3 (a) the firm line shews the profile of a wall for 20 feet depth of water in which the distance from the outer face to the reinforcement is, at every point, that obtained from the equation (18). The distance to the reinforcement from the inner face is taken as 2 inches throughout. As in the case of the walls under tension, it is assumed that the minimum average thickness of any height of wall is 6 inches. The dotted line shews the modification of the profile necessary to make it conform to this condition. Fig. 3 (b) shews the area of reinforcement in square inches required at each point, and Fig. 3 (c) the average equivalent thickness above each point on the assumption that $D = d + \frac{A}{3}$, where D is the equivalent thickness in feet, d the actual thickness, and A the area of reinforcement in square inches.

Table 2 shews the average equivalent thickness of walls for depths of water from 2 to 20 feet obtained from the foregoing formulæ, and also shews the ratio $\frac{D}{H}$ where D is the average equivalent thickness and H the depth of water.

TABLE 2.

AVERAGE EQUIVALENT THICKNESS OF WALLS AND RATIO TO DEPTH OF WATER, RESERVOIRS TYPE B. WALLS ACTING AS RETAINING WALLS.

Depth of Water. feet.	Average equivalent thickness of wall. feet.	Ratio.
2	1·01	·50
4	1·04	·26
6	1·12	·17
8	1·26	·16
10	1·46	·15
12	1·70	·14
14	1·96	·14
16	2·26	·14
18	2·54	·14
20	2·91	·15

It will be observed that it will be sufficiently nearly correct to assume that for all depths of water of more than 6 feet,

$$D = .15\ H \qquad \ldots \qquad \ldots \qquad \ldots, \qquad \ldots \quad (19)$$

As in the case of reservoirs with walls in tension, the equivalent thickness of the floor is taken as 1.0 feet.

For purposes of comparison the equivalent volume of concrete in the shell of the reservoir is

$$V = 2\pi r H \times .15 H + \pi r^2 \qquad \ldots \qquad \ldots \quad (20)$$

Substituting $r = \sqrt{\frac{C}{\pi H}}$ this becomes;

$$V = \cdot 532 \sqrt{C}\ H^{3/2} + \frac{C}{H} \quad \ldots \qquad (21)$$

Differentiating and equating to zero

$$\frac{dV}{dH} = \cdot 798 \sqrt{C}\quad H^{1/2} - \frac{C}{H^2}$$

$$H = 1{\cdot}094\ C^{1/5} \qquad (22)$$

The economic dimensions of reservoirs with walls acting as retaining walls, the equivalent volume of concrete in the shells, and the equivalent volume per 1,000 cubic feet capacity of the reservoir worked out from this formula are shewn in Table 3.

TABLE 3.

Economic dimensions and equivalent volumes of concrete in uncovered reinforced concrete reservoirs Type B. Walls designed as retaining walls.

Capacity of reservoir. cubic feet.	Economic depth of water. feet.	Economic diameter. feet.	Average equivalent thickness of wall. feet.	Equivalent volume in reservoir shell. cubic feet	Equivalent volume per 1000 cu. ft. capacity. cubic feet.
10,000	6·91	42·94	1·18	2,900	290
15,000	8·29	61·88	1·33	5,900	236
50,000	9·52	81·74	1·43	10,000	200
75,000	10·33	96·12	1·55	13,800	184
100,000	10·94	107·88	1·61	17,100	171
150,000	11·87	126·84	1·66	22,700	151
200,000	12·56	142·80	1·76	28,800	144
300,000	13·63	167·28	1·91	39,400	131
400,000	14·45	186·80	2·02	49,400	124
500,000	15·[illegible]	205·40	22·11	58,500	117

Fig. 4 shews graphically the economic depths and equivalent volumes per 1,000 cubic feet capacity for both types of reservoir. It will be seen that up to a capacity of 112,000 cubic feet it is more economical to design uncovered reservoirs with walls in tension. For larger capacities it becomes more economical to design the reservoirs with walls acting as retaining walls.

CONCLUSION.

Several interesting points are brought out by the foregoing investigation. These may be summarised as follows:

(a) in circular reservoirs, with walls designed to resist the stresses caused by the outward pressure of the water wholly by the tension on the horizontal reinforcement, the theoretically correct ratio of the area of the latter is 1.737% of the vertical cross sectional area of the concrete at all points in the wall below top water level.

(b) the theoretical economic depth of water in an uncovered reservoir of this type is a constant. In the conditions assumed in this paper, this constant is 13 per feet for all reservoirs of 56,000 cubic feet capacity and over.

(c) in reservoirs of smaller capacity the theoretical average thickness of the walls becomes too small for practical construction. In these cases it is assumed that the thickness of the wall is maintained at the minimum considered permissible (in this paper taken to be 6 inches) and the ratio of reinforcement to Concrete reduced.

(d) the economic depth is then not a constant but diminishes to some extent with the capacity of the reservoir

(e) in reservoir walls designed to act as retaining walls it is more economical to reinforce near the inner face against tension only, than to reduce the thickness of the wall by reinforcing also near the outer face against compression.

(f) in this type of wall the correct ratio of area of vertical reinforcement to horizontal cross-sectional area of concrete, when reinforced against tension only, is ·934% at every point. For practical purposes this is taken as 1·0%.

(g) on this assumption the theoretical economic depth of circular reinforced reservoirs with walls designed as retaining walls is given by the equation,

$$H = 1.004\ C^{1/5}$$

Where H is the depth of water in the reservoir in feet and C the capacity of the reservoir in cubic feet.

(h) from the tables and diagrams in the paper it will be seen that for reservoirs of capacities below 112,000 cubic feet it is more economical to design the walls to resist the thrust of the water by means of the tension in the lateral reinforcement. Above that capacity it is more economical to design them as retaining walls.

FIG 1.

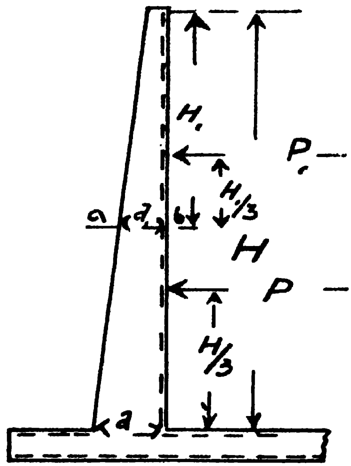
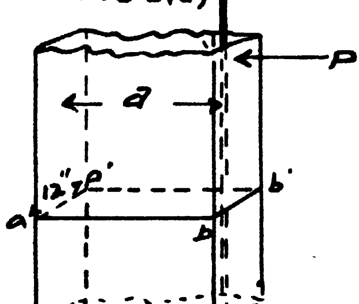


FIG 2(a)



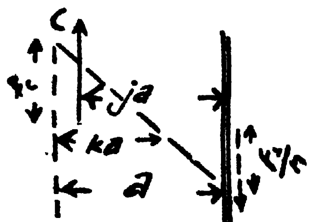


FIG 2(b)

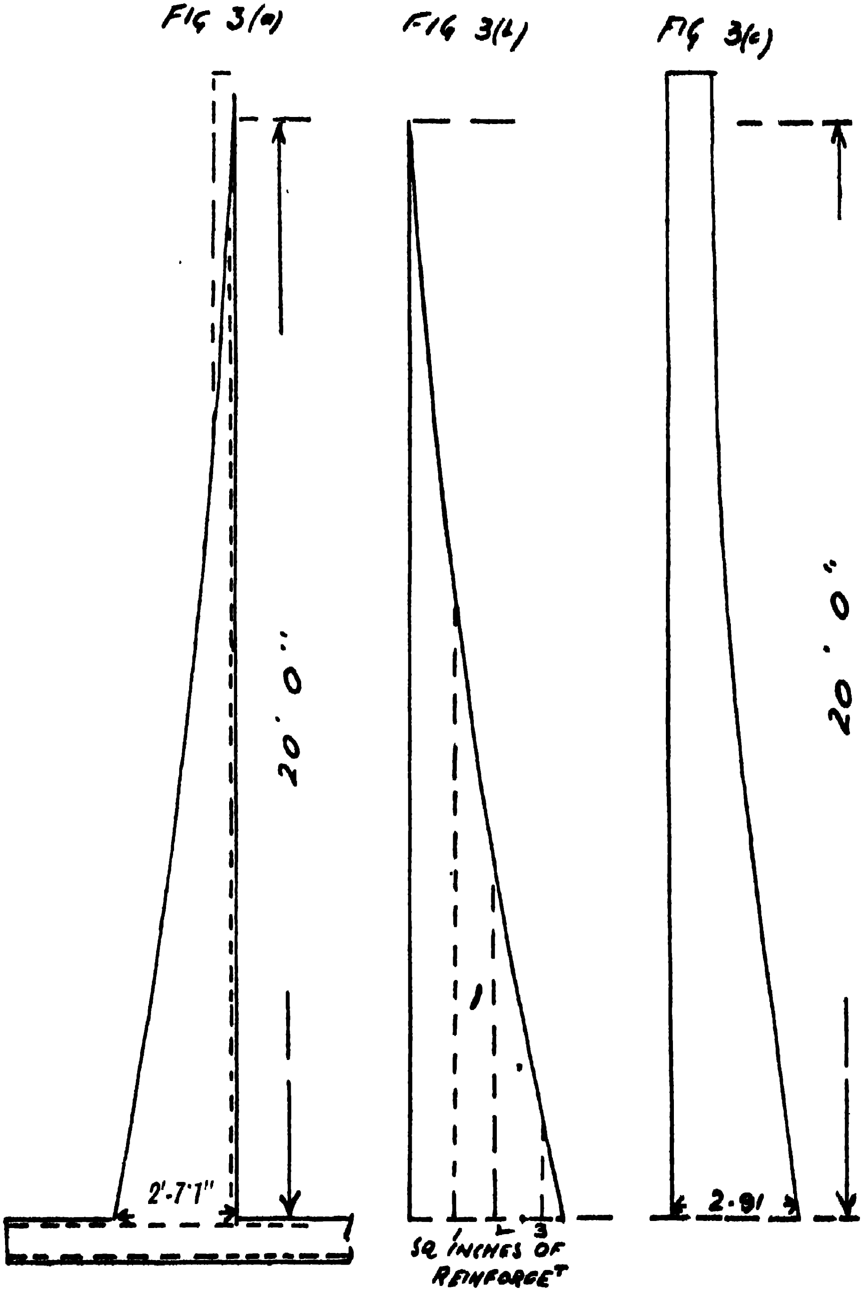
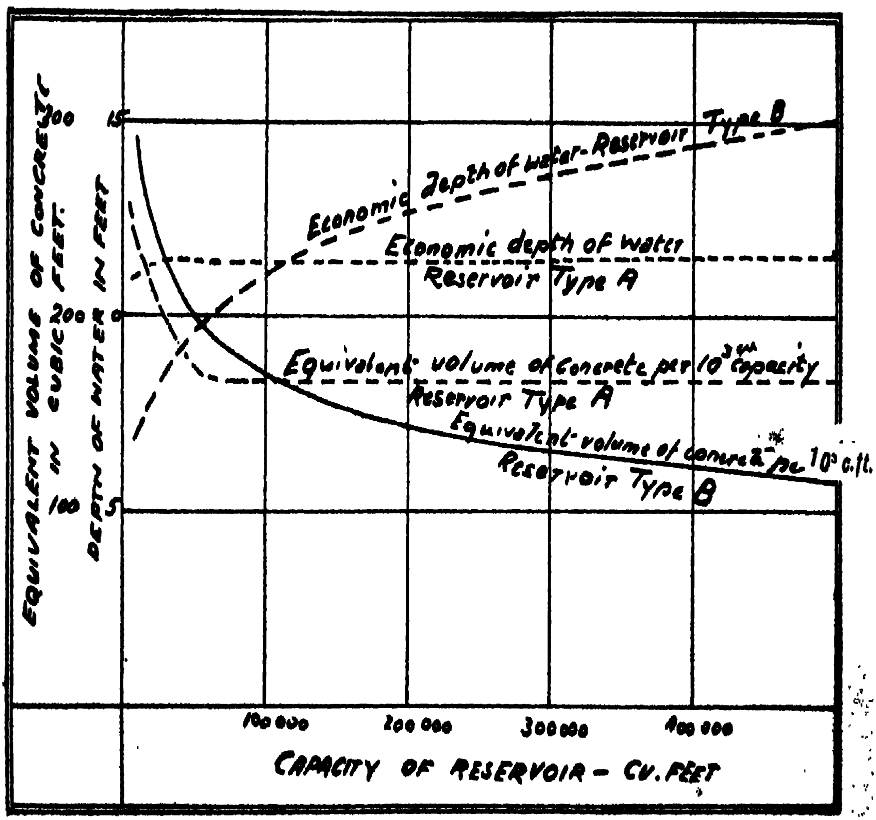


FIG 3(a)
FIG 3(b)
FIG 3(c)
20' 0"
2'-7·1"
1
1
2
3
SQ INCHES OF
REINFORCEᵀ
20' 0"
2·91

FIG 9.
DIAGRAM SHEWING
ECONOMIC DEPTHS, AND EQUIVALENT VOLUMES
OF CONCRETE PER 1000 CUBIC FEET CAPACITY
IN RESERVOIRS TYPES A & B



DISCUSSION ON
THE ECONOMIC DIMENSIONS OF REINFORCED CONCRETE RESERVOIRS.

Mr. G. F. WALTON remarked that the writer of the paper recommended a circular tank of more than 110,000 cft. to be designed with walls as cantilevers fixed at the base. But it was questionable whether it was advisable to design such a tank with cantilever walls without any provision for bursting. According to Dr. Reissner's theory, which was considered to be the most up-to-date theory, there must be bursting pressure in the wall of a tank, unless the diameter was infinite or height was zero, which was practically absurd. It had been assumed that the cost of shuttering was constant for all diameters. But it had been revealed by practical experience that for circular tanks the cost of shuttering was inversely proportional to the diameter of the tank. For a circular tank the main trouble would be to fit in the planks to the profile of the perimeter. The smaller the diameter the more was the difficulty. Also there was trouble in fixing and laying steel to the curvature which meant extra cost. When, however, the tank was very large, for a small length, say 10′ to 12′, the circumference was practically straight and there was no difficulty in placing shuttering or steel. It had been assumed that the concrete to be used was 1 :2 :4, but it had been found that a mixture of 1 :1½ :3 or 1 :2 :3½ was required to ensure watertightness, which meant the more one saved in the concrete section the more economical the tank would be. In a 200,000 gallon tank (overhead octagonal tank) the actual cost of shuttering was Rs. 4,025/- and the actual cost of 1 :1½ :3½ concrete was Rs. 5,236/- based on Calcutta price, so the price of shuttering was not equal to that of concrete as assumed. It was also important to allow for proper supervision, which would be a much greater percentage of the cost of small tanks than for large ones, especially if the tanks were situated a long way from the headquarters of the contracting firm. Mr. G. F. Walton.

DR. M. A. KORNI remarked that the limitation of stresses for circular tanks—175 lbs. per square inch in concrete and 12,000 lbs. per square inch in steel could not be considered as a helpful proposal towards economic dimensions of reinforced concrete reservoirs. Dr. M. A. Korni.

In order to be economical, the designing of reinforced concrete reservoirs would have to follow the way already adopted in Europe of the general progress of obtaining a concrete of high ultimate stresses. Let the stresses obtainable in cubes after 28 days for a concrete of different ultimate stresses be tabulated and called Cub. 28. It was found that a reservoir could be designed adopting axial tensile stresses as shown in the table below, without fear of the development of any description of cracks causing consequent leakage. As a general rule the axial tensile stresses SA should not exceed 1/9 cub. 28 and bending tensile stresses Sb should not exceed 1/5 cub. 28.

Ultimate stress cub 28 Lbs/sq inch Cub. 28.	Axial Tensile stress. SA Lbs/sq. inch SA	Bending tensile stress Sb Lbs/sq inch. Sb	Admissible Ring tensile stress. *fr*	Admissible bending tensile stress *fc*
2,500	278 lbs	500	180 lbs	360 lbs
3,000	331 ,,	600	200 ,,	428 ,,
4,000	445 ,,	800	280 ,,	570 ,,

A 4,000 lb. concrete was easily obtainable in India even in field conditions. The working stress in steel taken as 12,000 lbs. per square inch seemed to be very low. On the Continent the stress in steel adopted was 1200 Klg cm² which was equivalent to 17,760 lbs. per square inch, or say 18,000 lbs. per square inch. Moreover, the practical side of designing had shown that any working tensile stress had very little influence on the concrete, which would be proved later. Therefore the following stresses had to be considered in designing a reservoir in reinforced concrete with economic dimensions in view. Let two kinds of design be sidered. Firstly, when the tensile stress in concrete was in collaboration with the tensile stress in steel. This meant that the total tensile force of the reservoir was partly taken up by the concrete. Hence a crack in concrete meant a general weakening in construction. Secondly, when the total force was taken by the steel only, neglecting the stress in concrete. This meant that a crack in concrete did not cause weakening in system but leaking. In the first case

f concrete $= \frac{T}{bd + 15 A_s}$ and in the second f steel $= \frac{T}{A_s}$.

Where

f concrete = admissible stress in concrete.

f steel adm le stress in steel.

Dr. M. A. Korni.

T = Tensile force in ring or ring force.

d = average thickness of wall of reservoir.

A_s = Area in steel.

As case II was not acceptable in designing reinforced concrete tanks, a combination of the two assumptions must be considered and the two formulæ combined would result in a stress in concrete.

$$f\text{Concrete} = \frac{T}{bd + \dfrac{15\,T}{f\text{steel}}}$$

and from this formula the average wall thickness would be estimated at

$$d = \frac{T}{b} \times \frac{f\text{st} - 15 f\text{con}}{f\text{con} \times f\text{steel}}.$$

From this it would be seen that the economic value of a circular tank, when the cost of concrete dominated the cost of steel, would be entirely dependent on the working stress in steel and the admissible stress in concrete. Dr. Korni also considered n=15 to be more appropriate for the reason that the relation of the elastic modulus in steel and concrete in India was nearer to 15 than 10 or 12. If the construction of a reservoir was in the hands of conscious supervisors who could make a dense concrete without air holes, and get a steady uniformity in ultimate strength from 4,000—5,000 lbs. per square inch, even then it was not advisable to go below the above figure. He referred to the paper by Prof. B. Löser, the world famous designer of tanks, which was printed in Berlin in 1933. As regards the effect on concrete by stressing steel a numerical example might throw more light on the subject.

Assuming a 12 inch strip "b" of a circular reservoir was loaded with a tensile force T = 40,000 lbs. and the average cube test in 28 days showed an ultimate stress of 4,000 lbs. The admissible ring tensile stress as in Table above would be 280 lbs. per square inch which could be considered as safe. He assumed a working tensile stress in steel = 18,000 lbs. per square inch which was also admissible in India. The area of steel for design in case No. 2 where the total stress was transferred to steel only

would be calculated to $\dfrac{40{,}000}{18{,}000} = 2{\cdot}2$ inches²

$$d = \frac{40{,}000}{12} \times \frac{18000 - 15 \times 280}{280 \times 18000} = 9{\cdot}1''$$

For case 1 the total stress in steel would be only 15 × 280 or 4,200 lbs. per square inch.

Due to the stress the specific strain in steel

$$\frac{f_{st}}{E} = \frac{\Delta l}{l} \times \frac{4{,}200}{30{,}000{,}000} = 0{\cdot}00014 = \frac{1}{7{,}000}$$

Assuming a working tensile stress in steel equal to 12,000 lbs. per square inch in this case

$$A_s \quad \frac{40{,}000}{12{,}000} = 3.85 \text{ square inch and}$$

$$d - \frac{40{,}000}{12} \quad \frac{12{,}000 - 15 \times 280}{280 \times 12{,}000} = 7.7 \text{ sq. ins.}$$

Here also the stress in steel fst. = 15 × 280 = 4,200 lbs. per square inch and the specific strain $\frac{\Delta l}{l} = \frac{4{,}200}{30{,}000{,}000} = 0.00014$.

In both cases the specific strain, which had an influence on the concrete, was the same but due to the acceptance of a low tensile stress in steel the author had increased the steel area from 2.5 square inches to 3.5 square inches, which was not an economical proposition in the case when the cost of increasing the amount of steel dominated over decreased cost of the thickness of the wall. Taking the results in concrete stresses with the different admissible stresses—

in steel = 18,000 lbs/sq. inch, ... (1)

in steel = 12,000 lbs/sq. inch. ... ... (2)

it would be seen that in the first case the area of concrete

A_c = 9.1 × 12 = 109.2 sq. in.

and in the second A_c = 7·7 × 12″ = 92·4 square inches.

(1) $$f\text{concrete} = \frac{40{,}000}{109{\cdot}2 + \frac{15 \times 40{,}000}{18{,}000}} = 280 \text{ lbs. per square inch.}$$

(2) $$f \text{ concrete} = \frac{40{,}000}{92{\cdot}4 + \frac{15 \times 40{,}000}{12{,}000}} = 280 \text{ lbs. per square in.}$$

This showed that it did not matter if the working stress of steel were taken as 18,000 or 12,000 but it proved an economy in steel.

In the paper the author named "T" as total tensile stress. In reality T = Area × stress which was a force, therefore T should be, in the speaker's opinion, inserted as a tensile force.

The author gave only two classifications of circular tanks. Dr. M. A. Korai.

A. Reservoirs designed to take up the bursting stresses only.

B. Those taking up bending stresses.

Although it looked very simple, it was not in accordance with the classifications done by engineers in different countries. In the last decade a very exact theory had been laid down by a famous engineer Prof. Doctor Eng. Müller-Breslau and further developed by Dr. Runge and Dr. Reissner and the Italian Prof. Pinetti. There was a strong view that a circular tank was subject to bending stresses and bursting or ring stresses as well and only special dimensions could partly eliminate one of the two stresses. This elimination depended on characteristic factors of a reservoir named K which was

$$K = \frac{12H^4}{\left(\frac{D}{2}\right)^2 d^2}$$ (Vide Figs. Nos. 1, 2 and 3).

The factor K decided where the distribution of pressure ceased to be two way and became one way, either in the direction of horizontal rings or in the vertical direction. The limiting value of K to determine this was $K = \infty$ and $K = 0$. When $K = 0$, all the pressure was taken in the vertical direction and when $K = \infty$ all the pressure was taken up by horizontal rings, but both the cases were practically absurd, as H must be zero for K to be zero and D must be zero (and H infinity) to make $K = \infty$. Hence in all cases both the stresses were present although one was predominant over the other. Therefore it would not be theoretically correct according to Dr. Reissner's theory to neglect one altogether as was assumed by the author. Taking a concrete example from table No. 2 of the paper—a reservoir of 15′ depth, diameter 205′ and thickness of wall 2·2′ had K = 30. Although the stress was practically taken in the vertical direction, there was a lot of bursting pressure (which depended on water pressure and diameter of tank) to warrant steel in horizontal direction. When the steel in the horizontal direction was added to the tank, it would not be economical. Also more reasonable thickness of

the wall was obtained by Dr. Reissner's method. The same reasoning applied to table No. 1, where the tank walls were designed for bursting pressure only. So in the speaker's opinion it was not the diameter of tanks that should classify them but the value of K. It might be of interest to mention the 24 circular reservoirs of different dimensions built in various countries which might be considered as classical types as they had undergone a strong competition. The appended table might also help the designers to select the right dimensions of a reservoir when dealing with the cost of it as the thick-walled reservoir indicated here that the cost of steel was prohibitive.

No.	Cont. in gallons.	Diam. D. feet.	Height H. feet.	Wall top thickness inches.	Thickness in the bottom. inches.	In the middle. inches.
1.	16,300	16	13.0	4.25	4.75	4.5
2.	22,400	16.4	17.0	6	6	6
3.	31,200	19.4	18.0	7.25	5.5	4.85
4.	38,500	20.4	16.8	8	8	8
5.	42,500	18.4	22.0	6	8	7
6.	50,000	20.5	26.3	4.25	6	5.12
7.	56,000	38	15.4	6	7.12	6.55
8.	56,000	29.0	15.0	4.25	8	6.12
9.	67,000	29.6	16.8	4.25	6.75	5.5
10.	67,200	30.0	18.7	4.25	7.12	5.68
11.	67,000	25.0	20.4	4.25	6	5.12
12.	67,200	27.5	18.4	4.25	4.25	4.25
13.	78,500	27.0	21.7	4.75	8.0	6.37
14.	112,000	29.5	22.4	4.25	7.12	5.68
15.	112,000	37.2	16.5	5.5	7.12	6.31
16.	135,000	41.0	21.4	6	10	8
17.	135,000	34.8	26.2	3.25	8	5.62
18.	224,000	33.0	42.5	4.25	10	7.12

Dr. M. A. Korni.

No.	Cont. in gallons	Diam. D. feet.	Height H. feet.	Wall top thickness inches	Thickness in the bottom. inches.	In the middle. inches.
19.	224,000	50 0	17 0	5.25	12	8.62
20.	224,000	42 0	20 0	3 25	17 5	10 37
21.	224,000	40 8	26 0	7 65	18 5	10 62
22.	448,000	51 8	36 0	7 12	14 5	10.31
23.	448,000	46 0	42 0	6 0	22.25	14.12
24.	448,000	59 2	26 0	8	14.25	11.12

The Author.

In reply to the remarks of Dr. M. A. Korni and Mr. G. F. Walton the author said that Dr. Korni had taken exception to the limitation of stresses in the paper to low figures. The author had purposely kept them low because a long experience of India had shewn him that it was unsafe to rely on a standard of workmanship or materials in that country comparable with those that could be depended upon in European countries.

Dr. Korni had given an interesting disquisition on the design of reinforced concrete tanks, but he had not suggested any alternative method of arriving at the results which the author had reached, nor had he produced any evidence to shew that these were seriously inaccurate. The fact that other engineers had used other classifications did not prove that the author's were not sound. The extreme divergences in the ratio Height Diameter in the table given by him led one to suppose that some at all events of the reservoirs classified must have been designed on an uneconomic basis. It was not stated whether the tanks were open or covered. In the latter case the economic depth became considerably greater. In any case however it was impossible to conceive any circumstances which would make a diameter of 33 feet and a height of 42 feet economical for a tank holding 224,000 gallons.

Both Dr. Korni and Mr. Walton referred to the fact that there was some bursting pressure in any circular reservoir. Undoubtedly there was and there were also vertical stresses in a tank

Author. built to withstand the water pressure by horizontal tension Secondary reinforcements would be required in the first case in the horizontal, and in the second in the vertical direction, but these would not seriously affect the author's conclusions.

Mr. Walton also referred to the fact that the cost of shuttering would not be constant. The author was aware of that fact but took what he considered an average. In Mr. Walton's example the ratio of cost of concrete/shuttering was 4/5, whereas the author had taken it as unity. The difference was not very serious.

COOLING WATER FOR DIESEL ENGINES

BY

GOVERDHAN, Associate Member.

The subject matter of this paper does not lay any claim to original research work nor does it embody intricate mathematical terminology and abstract theorization which is unfortunately or fortunately a feature of many of the articles appearing in modern engineering journals and which are, as such, of very little utility to the busy practical man in the field of operation. Amongst other things dissemination of useful professional knowledge which will help the engineer in tackling his difficulties in the working, is one of the important objects of any article or review and this brief survey on one of the most important subjects to the Diesel Engineer keeps the above view in the forefront.

It is a well known fact that for proper cooling, cylinder heads and jackets and in certain cases, pistons and exhaust valves, etc., of Diesel Engines must get a plentiful supply of cool soft water at a suitable pressure head. Bad cooling water may be classified as follows :—

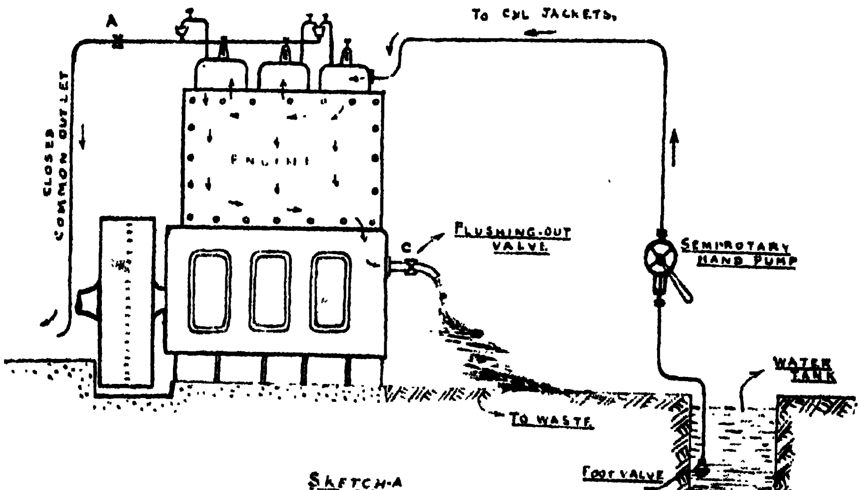
(a) Hard or scale forming water.

(b) Muddy water containing sludge, sand or slimy matter in suspension.

(c) Corrosive water.

Waters such as (a) or (b) will deposit scale or mud and sludge which will seriously interfere with the transfer of heat from the mass of engine castings to the jacket water with attendant troubles of knocking and overheating, cracking of cylinder heads, and, in the extreme cases, piston seizure with all its consequences.

Improper cooling of the liner body will destroy the film of oil between the piston and the liner walls, thus making the contact "metal to metal." If this condition is allowed to continue for sometime piston seizure will be the result and every engineer knows what it means. To avoid or minimize the risk of above troubles periodical examination of the cylinder heads and liner Jackets should be made and any scale deposits and mud removed. Removal of scale is a process which deserves detailed treatment by itself and will be discussed fully later on. Deposits of mud and sludge are amenable to simple flushing with water, preferably by means of a hand pump as shown in sketch A.



SKETCH-A

Valve A on the common cooling water outlet from the engine cylinders should be kept closed, while Valve C should be closed and opened alternately to allow the water to agitate and shake the deposits before passing out to waste. The hand pump may be fixed on a wall or pillar somewhere near the engine, or wherever convenient, with its delivery pipe connected to one of the cleaning doors on the cylinder cover, and the suction pipe leading to the water.

Chemistry of Hard Water. 'Hard water' contains calcium or magnesium salts in solution, the amount of these present determining the "degree of hardness." Hard water does not give lather with soap, the calcium and magnesium salts combining with the fatty acids of the soap to form insoluble compounds. The soap destroying power of a certain water is an indication of its

hardness and the extent or degree of hardness is expressed in grains per gallon of Calcium Carbonate or its equivalent present in one gallon of water. Hardness is of two kinds, *viz.* :—

(a) Temporary hardness.

(b) Permanent hardness.

'Temporary hardness' is caused by the presence of calcium and magnesium bicarbonates, $CaHCo_3$ and $MgHCo_3$, and is removed by boiling, the bicarbonates getting precipitated as insoluble carbonates.

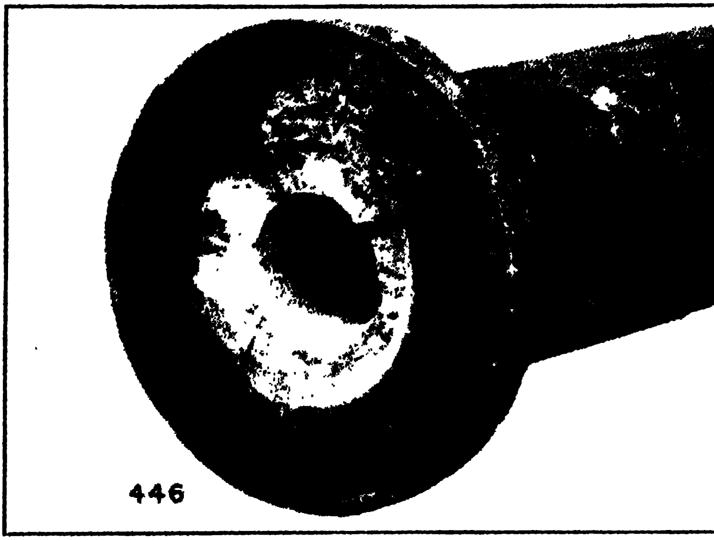
"Permanent hardness" is caused by the presence of calcium and magnesium sulphates, chlorides and nitrates and is not removed by boiling.

Measure of Hardness : The bicarbonates of lime and magnesia make water alkaline to indicators like methyl orange or alizarin paste. The amount of acid required per gallon to make the water neutral is a measure of temporary hardness and is expressed in grains per gallon of $Ca\ Co_3$ needed to combine with it, the figure thus obtained being termed temporary hardness. Temporary hardness is thus the alkalinity of water expressed in grains per gallon of calcium carbonate ($CaCo_3$). One degree of hardness means one grain of calcium carbonate per gallon.

On the other hand, if alkali is added to water containing the more stable forms of Calcium and Magnesium like Sulphates, Chlorides and Nitrates, the bases forming these salts are precipitated, more or less alkali being used up which can be determined by an acid test. Thus it is possible to determine the alkali destroying power of these salts in a gallon of water and express this in terms of their equivalent of lime Carbonate. The figure so obtained is Permanent Hardness. Permanent hardness is expressed in degrees per gallon, one degree being the equivalent of one grain of Calcium Carbonate per gallon.

Scale—its Composition and Formation. Scale as found in the water Jackets is a white stony deposit of granular consistency consisting of the precipitated Ca and Mg salts, *viz.*, $CaCo_3$ and

Mg Co_3, contained in hard cooling water where such is allowed to circulate. This scale is of varying thickness according to the time given it to build up undisturbed. It adheres to the walls of water spaces as shown by the sketch below.



EXAMPLE OF SCALE FORMATION.

The formation of hard scale deposit in the bore of this pipe has reduced its effective diameter from 6 inches to 3¼ inches and its effective section from approximately 28 sq. inches to 10 sq. inches.

It is a significant fact that hard or scale forming water is as harmful to man as to his machinery. In man the drinking of hard water contributes to the deposition of salts within the arteries, hardening them and thus reducing the passage of blood circulation to produce a condition known to medicine as "arteriosclerosis."

Similarly in Diesel Engines or any water cooled engines for the matter of that, the formation of scale besides retarding the transfer of heat, also reduces and ultimately chokes up the available water spaces, the nett result in either case being the impaired functioning of the entire system. "A man is as old as his arteries" is a saying well known to the medical profession and if the scale once formed inside the jackets was impossible to remove effectively, the Engineer might as well say "An engine is as old as its water Jackets." The remedy too in either of these cases is identical,

viz., the clearing away of harmful deposits by suitable solvents. Scale forms as follows :—

(a) By decomposition—$CaHCo_3$ and $MgHCo_3$ or Calcium and Magnesium bicarbonates being broken up and $CaCo_3$ and $MgCo_3$ or Calcium and Magnesium Carbonates thrown out of solution.

(b) By decreasing solubility—Calcium Sulphate in excess of 10 grains per gallon being thrown out at high temperatures.

(c) By concentration through evaporation—residual quantities of various solids in solution being thrown out as the solution reaches the saturation point for one. The deposits thus formed are of different types, soft and sludgy when Carbonates are present, hard and crystalline in case of Calcium Sulphate.

Other substances like FeO, Al_2O_3, SiO_2, $Mgcl_2$ (Nacl in case of sea-water) are also present.

Briefly stated, the evils of scale formation manifest themselves as follows :—

(a) Overheating, resulting in cracked pistons, and other parts exposed to combustion.

(b) Cracked cylinder heads.

(c) Rapid liner wear.

(d) Tendency to piston seizures.

(e) Power reduction through distorted valves and seatings.

Remedies for the above troubles fall under the two main heads of prevention and cure, and 'prevention is always to be preferred to cure.'

(A) *Preventive Measures.* Where start is made with clean Jackets, as for example, with new engines, and one is lucky enough to get soft water for use, there is nothing much to do except examining the Jackets at regular intervals, say every three months, and flushing with clean water if necessary.

Certain waters although they look quite clear deposit sand and sludge and hence the necessity for periodical inspection. A low water outlet temperature from individual cylinders does not always indicate that the cooling is efficient. The parts may be getting overheated in spite of the outlet water keeping cool, because deposits greatly retard heat transfer from the mass of castings to the cooling water.

As differences in the outlet water temperatures also point to unequal loading, it is to be carefully ascertained in cases where one or more cylinders show higher temperatures whether the apparent temperature rises are really a symptom of scale formation.

B. When the water, however, is suspected to be very hard, or at any rate moderately so, the engineer would be well advised to tackle the problem of softening the same in a systematic way. The best plan is to get a sample of water chemically analysed and to base the softening process to be adopted on the results of such analysis. Any haphazard methods, *viz.*, the daily addition of a small amount of soda ash, as done sometimes, are likely to do more harm than good, as instead of removing the objectionable salts from solution, the soda ash will go to increase the concentration thereof and thus make matters worse.

Chemical Analysis of Tube Well Water. D—19th Dec. '32.

Condition of water at time of analysis:

Appearance . . . Slightly turbid. Odour . . . Nil.

Sediment . . . Trace. Reaction . . . Alkaline.

Results expressed in parts per 100.000.

Mineral Analysis.

Total solids derived at 110°C	= 55.12
Alkalinity Calculated as Calcium Carbonate	= 38.8
Silica (SiO_2)	= 2.64
Oxide of Iron and Alumina	= 0.24
Iron as Fe	= 0.084
Lime (CaO)	= 15.53
Magnesia (MgO)	= 6.78
Sulphates (SO_4)	= 2.58
Chlorides (cl)	= 2.84
Nitrates as KNO_3	= 6.50
Free Carbonic acid	= 1.67

Probable Composition of Total Solids.

Calcium Carbonate	= 27.72
Magnesium Carbonate	= 9.34
Magnesium Sulphate	= 4.26
Magnesium Chloride	= 2.12
Sodium Chloride	= 2.08
Oxide of Iron and Alumina	= 0.24
Silica	= 2.64
Potassium Nitrate	= 6.50

Hardness in grains per gallon.

Total Hardness	=	**31.2**
Temporary Hardness	=	**27.2**
Permanent Hardness	=	**4.0**

Tube well waters demand special vigilance in this respect. They are often not only exceptionally hard but corrosive in nature. The foregoing report on the analysis of a typical tube well water which the writer got analysed for his engines is quite interesting It will be noted that the percentage of free carbonic acid gas is 1.67, and this is likely to be much more, when the water is fresh. The percentage of $MgCl_2$ is 2.12. The presence of these two substances makes the water quite corrosive.

When a water is hard it may be softened in one of the following ways.

(a) The Lime Soda or "Clark's process" of softening formulated by Dr. Clark over seventy years ago relies on a definite chemical reaction between the constituents of the hard water and a reagent which is added. As a result of this reaction the "hard" constituents are precipitated and allowed to settle out of the water, the final product being filtered to ensure perfect clarity. The process, being very common on grounds of cheapness is as follows :—

Pure hydrate of lime, *i.e.*, slaked lime is added to remove temporary hardness which converts the Soluble Bicarbonates into Insoluble Carbonates. These latter get precipitated.

Sodium Carbonate or 'soda ash' is used to combat "Permanent Hardness" where it is sufficiently high to warrant removal.

The nature of reactions is as follows :—

(1) $Ca\,H\,(Co_3)_2 + Cao \quad Ca\,Co_3\downarrow + H_2o.$

(2) $Mg\,H_2\,(Co_3)_2 + Cao \quad Mg\,Co_3\downarrow + Ca\,Co_3\downarrow.$

(3) $Mg\,Co_3 + Cao \quad Mgo\downarrow + Ca\,Co_3\downarrow.$

(4) $Ca\,So_4 + Na_2\,Co_3 \quad Ca\,Co_3\downarrow + Na_2\,So_4.$

(5) $Mg\,Cl_2 + Cao = Mg\,O\downarrow + Ca\,Cl_2.$

(6) $Ca\,Cl_2 + Na_2\,Co_3 = Ca\,Co_3\downarrow + 2\,Na\,Cl.$

To determine the exact quantities of the reagents necessary the following tests may be made.

Lime or Cao: Place 210 cc of sample in a stoppered bottle. Add lime water of known strength in excess, shake the mixture well for about two hours, settle or filter and pipette off 70 cc. Titrate with N/10 Hcl, first using phenolpthalein as indicator and then methyl orange. Deduct the difference between the two from the figure obtained in the phenolpthalein titration. The result gives the lime in excess of what is actually required.

Soda or $Na_2\ Co_3$: Place 70 cc of sample in a platinum basin and add excess of N/10 $Na_2\ Co_3$. Evaporate the solution nearly to dryness, dilute slightly and then wash the precipitate with free-air water. Determine the excess of soda Carbonate in the filterate by titration with N/10 $H_2\ So_4$ (Methyl Orange.)

In practice, however, every engineer is either not a chemist or does not possess a well equipped chemical laboratory at his disposal to carry out the above tests and it is best to leave the matter in the hands of the firm analysing the sample of water. The exact amounts of the two reagents may then be known and added daily according to individual requirements. Alternatively, a firm of water treatment specialists may be written to, when they will be only too glad to quote for a suitable softening plant, giving the quantities of reagents required to be put in within the apparatus.

(b) *Base exchange softening.* The second process is that of softening by means of "Zeolite" a natural mineral consisting of double silicate of Sodium and Aluminium. This mineral has the property of removing the Calcium and Magnesium contents from a hard water in exchange for sodium.

The mineral, however, after it has parted with all its sodium contents would no longer be effective but can be regenerated by a strong solution of common salt or brine. The zeolite absorbs Na from the salt and becomes ready again for softening.

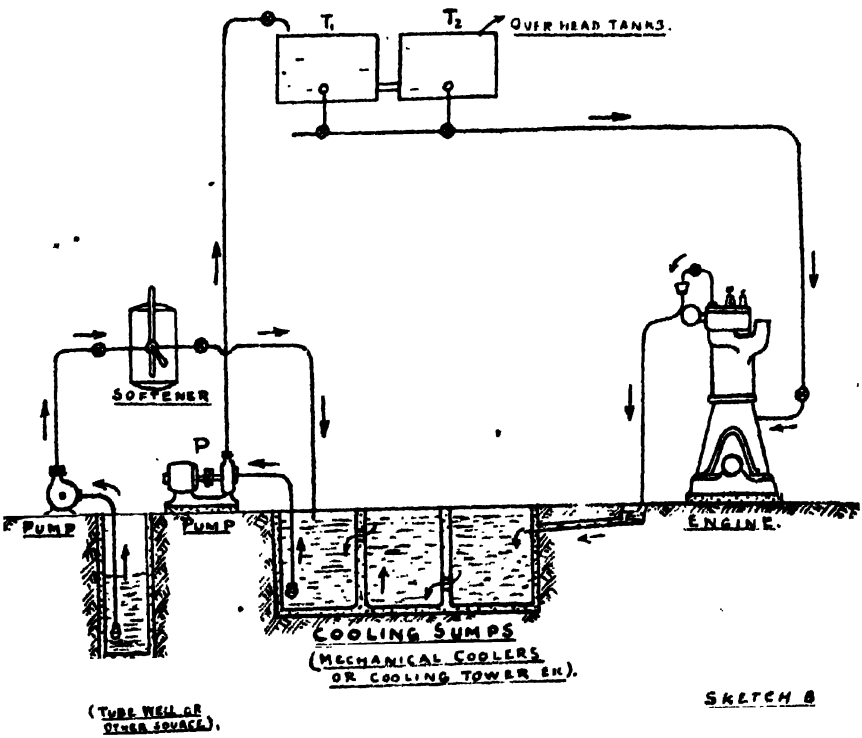
Various types of softeners using the above mineral are on the market and a suitable size can always be had to meet individual requirement.

Natural Zeolite better than synthetic Zeolite. It should be noted that many of the water softeners working on the base-exchange principle do not use the natural 'Zeolite' as such, but different preparations of Sodium Alumino Silicates Synthetically prepared. Such synthetic minerals go by different names.

"Permulit," now obsolete more or less; "Basex"; Jewellite A; Jewellite B, etc., etc., are examples of synthetic "Zeolite." Artificial or synthetic Zeolite does not compare quite favourably with natural Zeolite, particularly when the water to be treated is corrosive and contains excess of Co_2. The former being porous and crystalline is very much subject to the scouring and dissolving action of water, and a plant charged with it requires less per gallon of treated water and is hence cheaper in first cost and more compact in size. The latter is a hard greenish coarse sand with lasting properties that are superior to synthetic materials.

Against the low initial cost of a plant charged with the synthetic mineral, one has however to consider the cost of subsequent refills which heavily outweighs the first advantage and is by no means a negligible item.

Determining the size of the Softener. A word of caution is here necessary with regard to the size of softener to be installed. As a general rule, with open type cooling as illustrated in diagram



SKETCH B

it will be necessary to soften the make-up supply only, which may be roughly estimated at about 5% of the quantity of water

contained in the cooling sumps or in circulation. It should however be considered imperative to lower the level of water in the cooling sumps from time to time, by running some water to waste from the overhead tanks T_1 and T_2 (sketch B.) and then make up the loss with fresh soft water. This will prevent the concentration of salts in the water reaching a saturation point and thus enhancing the tendency to rapid scale deposition. From this it will be evident that the softener will be required to furnish not only the daily make up supply of 5%, but will have to cope with the occasional draining of the tanks T_1 and T_2 as already explained. The writer prefers to fix up the size of softener so that it can deal with three times the amount of daily make up water each day with one regeneration. However this is a question of individual requirements and local conditions and a hint here was considered seasonal.

Rain water being an ideal cooling water, advantage should be taken, during the rains, of collecting as much of this heavenly gift as possible by lowering the level of water in the cooling sumps which can be easily done by draining the overhead tanks T_1 and T_2 according to the amount of rain water available at a stretch. This will greatly dilute the concentration within the sumps by furnishing a copious addition of pure soft water.

Discharging to waste. Most of the Power Houses in this country cannot afford to let the discharge from the engines run to waste, and hence the precaution of softening the water in circulation to practically zero hardness before giving it to the engines is very essentiel. Where possible, however, as in the case of water works or pumping installations, it is ideal to waste the outlet water from the engines, there being a plentiful supply of fresh water always in store. Where this is done it will be noticed that even hard water will not leave any very noticeable scale deposits. The life of the engine liners is considerably increased there being hardly any serious wear say even after 4 or 5 years, whereas if the same water was used over and over again, the liners might possibly be ready for renewal as early as after a year or so. The writer knows of certain stations where the water was so hard that unless extreme vigilance was exercised by the running staff, the liners had to be renewed practically every two years and the cracking of cylinder heads was a common occurence.

C. Investigation has proved that most of the scale deposition within the water spaces occurs on shutting down the engine. The reason for this will be evident if the different processes of scale formation already discussed have been carefully followed vide

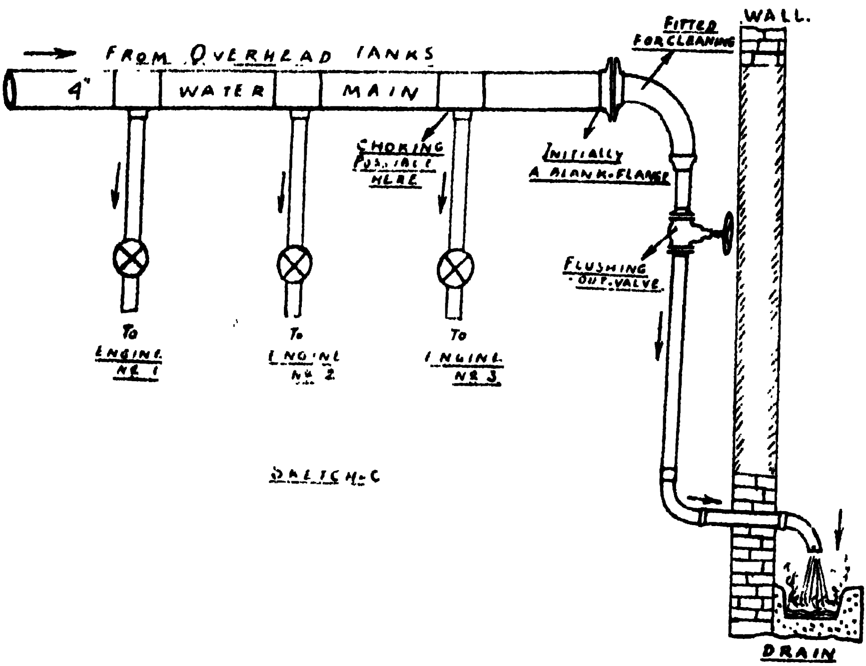
items (a) and (b) under the heading "Scale forms as follows." Let us see what actually happens when the supply of cooling water is turned off as soon as the engine is stopped. The entire heat contained in the mass of castings gets busy heating and boiling the jacket water and thus facilitating the rapid precipitation of scale forming Ca and Mg salts. In fact it has been observed that the number of layers forming the scale correspond with the number of times the engine is started and stopped, thus establishing the fact that every stoppage is responsible for fresh scale deposits. It is therefore essential to keep the cooling water running through the jackets at least 15 to 20 minutes after the engine has been shut down. This simple rule must be held as sacred as the law of the Medes and Persians.

D. *Use of Boiler Compositions.* Where the water is not very hard or for one reason or other it is not considered worth while to install a water softener, the practice of a daily addition of some boiler fluid is sometimes followed. In this connexion it should be noted that whereas certain compositions are quite effective and cause the scale forming salts to separate as a soft easily washable sludge, most of them are only fakes of doubtful efficacy and probably injurious.

These so-called boiler-fluids or anti-incrustation mixtures are of various compositons, sometimes consisting of a weak aqueous solution of $Na_2\ Co_3$ or Na OH (caustic soda), but more often containing in addition, organic matter of a mucilaginous character (Irish moss, agar agar, starch or gum) tannins and other vegetable products belonging to the group of Colloids. Under special circumstances such compositions have their uses, but they should be used with caution for reasons alike of safety and economy.

E. General and periodical cleaning of the entire system including water pipes, drains and overhead tanks and cooling sumps. This is the last though not the least of the scale and sludge preventive measures. Wherever possible flushing out valves should be included in the water mains to avoid their getting choked up at an inconvenient moment. The writer was once faced with the uncomfortable situation of the inlet water pipe to one of the engines getting choked up just when she was ready to start up. As the peak of the load was due within a few minutes, there was no alternative but to open out the inlet water system part by part till the choke was detected and remedied. Thereafter to avoid this trouble repeating itself a flushing out valve

was fitted up the next day to the common 4" water main from the overhead tanks as shown in the sketch C and since then old man trouble has not shown his face again.

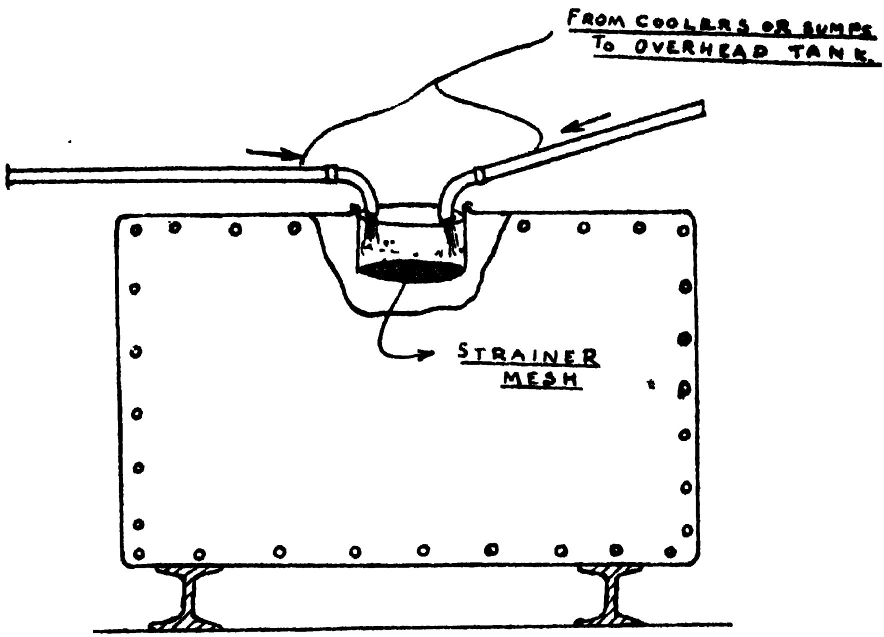


SKETCH-C

Green Moss:- A frequent nuisance with certain open cooling systems is the formation of a soft green velvety growth of vegetable origin. This manifests itself adhering to the walls of drains and cooling sumps like a soft layer of green velvet when new. At this stage it is a most beneficial thing, being an effective absorbent of dust and sand particles and helps in keeping the water in circulation clear like crystal. It also retards scale formation by adhering itself in a spongy protective layer over the Jacket walls, etc. Later on, under the influence of sun, it begins to rot changing into a dark slimy mud and joining hands with mud and sand accumulates at and chokes up the inlets and outlets of water. This makes the inspection and flushing out of Jackets periodically very essential, and the cleaning of tanks and coolers more frequent.

Further, to avoid this slimy stuff getting into the overhead tanks and finally to the engines, it is advisable to install fine mesh strainers just at the discharge of the water from the circulating

pump outlets into the overhead tanks. A probable sketch of strainers may be as in diagram D.



OVER HEAD TANK.
(SHOWING STRAINER AT ITS MOUTH)
SKETCH-D

Devices such as shown above are only indicative and not exhaustive and would need modification and adoption to particular requirements.

Closed Cooling Systems. The growth of vegetable fungus or green moss as detailed above is a feature of most of the open cooling systems in vogue in the various Power Houses in this country, no matter whether the cooling is done by means of a cooling tower and pond or by mechanical coolers or by surface cooling in sumps or a combination of these. This means that unless the passage of cooling water to and from the engines, in circulation, is totally enclosed, the growth of fungus and moss nuisance is more or less a natural phenomenon. An example of a totally closed system is provided by the cooling systems of certain Diesel Electric Locomotives or Diesel Engined cars and lorries very much similar in principle and practice to the cooling of petrol cars and lorries. In such cases of course the problems and difficulties, inherent with the stationary open cooling, are

absolutely minimized or totally absent. On certain locomitives the cooling of the Diesel Engines is effected by circulating the water through honey-combed radiators mounted on the locomotive roof. The radiators themselves are positively cooled by motor blowers of the propeller types although the draft of natural ventilation when the locomotive is running materially assists the cooling for the most part.

Now let us proceed to the:

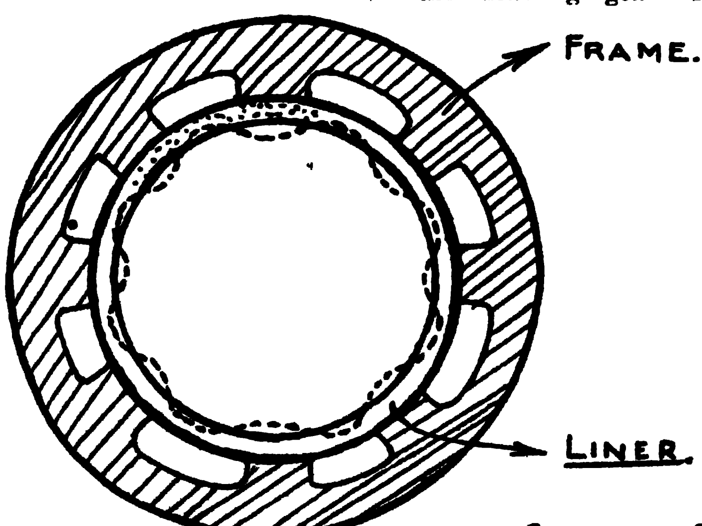
Curative Measures of scale deposits.

These are mainly two, *viz.*,

(i) Chipping.

(ii) Acid treatment.

(i) Chipping, however adequate, always leaves some part unattended to. It is very difficult, almost impossible, for the chisel to reach every nook and corner of cylinder head castings. Also, it does not suffice to merely wash out the loosened deposits. For thorough cleaning the liners must be withdrawn from the frames. Some of the old type liners are indeed very difficult of removal and involve extra strain on the drawing gear. This is



SKETCH-E

because they are initially a tight fit with the frames at three different places, *viz.*, across the middle, and top and bottom, making it a devil's job to pull them out when worn, and prone to piston seizures.

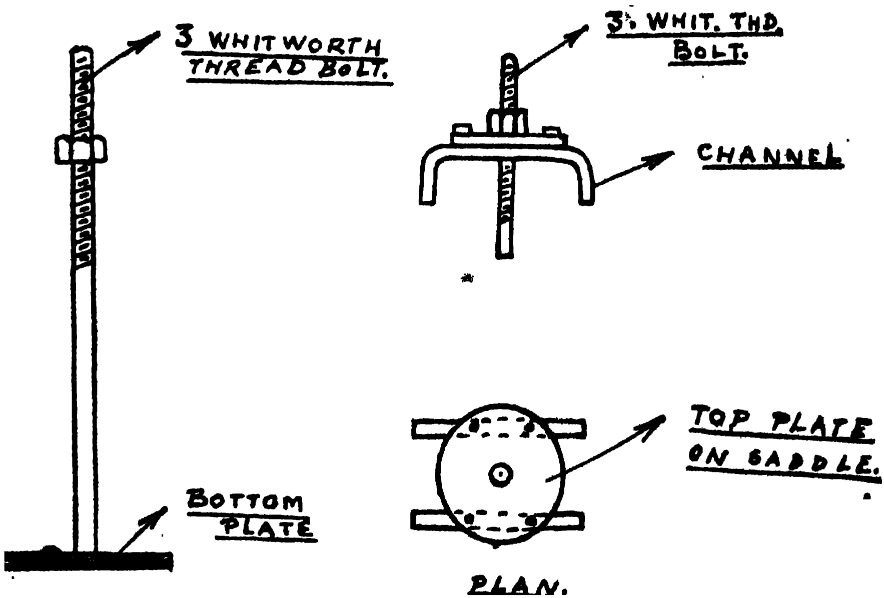
Let us at this stage review more closely the phenomenon of piston seizure in the case of modern type of liner which is, initially a slack fit at the belt and free to expand longitudinally under temperature during working. The accumulations of rust and scale

from the cooling water grip the liner tight at the bottom thus preventing it from expanding lengthwise as it should. The belt in the frame being made of a number of symmetrically placed segments, and the deposited scale and sludge exerting an external pressure, the liner in expanding assumes a wavy or sinuous shape as shown by figure E (page 14).

Between the segments the cylinder diameter is more than normal. Across the segments it is actually less. This will explain why, after serious scale deposits have taken place, enormous force has often to be exerted in pulling out a liner which initially could be easily withdrawn by an ordinary crane.

A very useful liner drawing gear is illustrated in diagram F.

Pulling the liner top by a 5 or 10 ton crane and suitably jacking it up from below is also very effective.



SKETCH OF
LINER DRAWING GEAR.-F.

Acid treatment is a most effective method of getting the liner jackets and cylinder heads clear of scale, especially so when the cleaning has to be done within the shortest possible time. In the case of cylinder heads it is the only process, as in the writer's opinion the so-called cleaning doors on most of the modern engines are mere inspection holes and no more.

Acid treatment has, however, two very serious drawbacks, *viz.*, that it attacks the cast iron very vigorously and also sets up electrolytic action between the ferrous cylinder and the yellow metal quills where these are fitted up.

The latter trouble can be overcome by smearing the quills with grease all over. When the cylinder is splash lubricated, there are no quills to be worried over.

The action of the acid on cast iron can, however, be made abortive or practically stayed by the addition of substances known as Inhibitors, to the acid solution before filling. One of the best known Inhibitors is the "Mirrlees Inhibitor," a chocolate coloured powder produced by the well known firm of Messrs. Mirrlees Bickerton & Day Ltd. The Inhibitor is known as such because it "inhibits" the action of the acid on cast iron or steel castings, while allowing its action on the scale to proceed unhampered to any very appreciable extent.

A 10% solution of commercial Hydrochloric acid may be used for acid washing. If it is necessary to expedite the cleaning, stronger solutions, say 30% or 50%, can be used, but generally if the scale is not very thick, a 10% solution would meet the ends of justice. To prepare the solution, mix 9 parts of water with 1 part commercial hydrochloric acid.

Now, weigh separately 1% (by weight of the sol) of Inhibitor, dissolve it in a bucket of water, and add to the acid solution. Fill this into the water spaces to be de-scaled and keep it there till the solution has exhausted itself. This can be tested by adding a piece of zinc to the solution separately till there is no effervescence. Before filling in the solution, do not forget to provide vents or holes for the escape of gases given off during the process. Be careful not to allow any naked lights or flame near the engine while the de-scaling is going on. Better results can be obtained by circulating the acid slowly by means of a hand pump.

Finish by draining out the solution and flushing thoroughly with clean water. It is better if a soda solution is used for the final wash out. Chemical representation of the de-scaling may be represented as follows :—

1. $\underbrace{CaCo_3 + CaSO_4}_{\text{scale}} + 4\ Hcl = 2CaCl_2 + Co_2\uparrow + SO_3\uparrow + 2H_2O$

2. $2Fe + Hcl = FeCl_2 + 2H\uparrow$ (nascent)

Tendency for the latter reaction is kept under control by the Inhibitor.

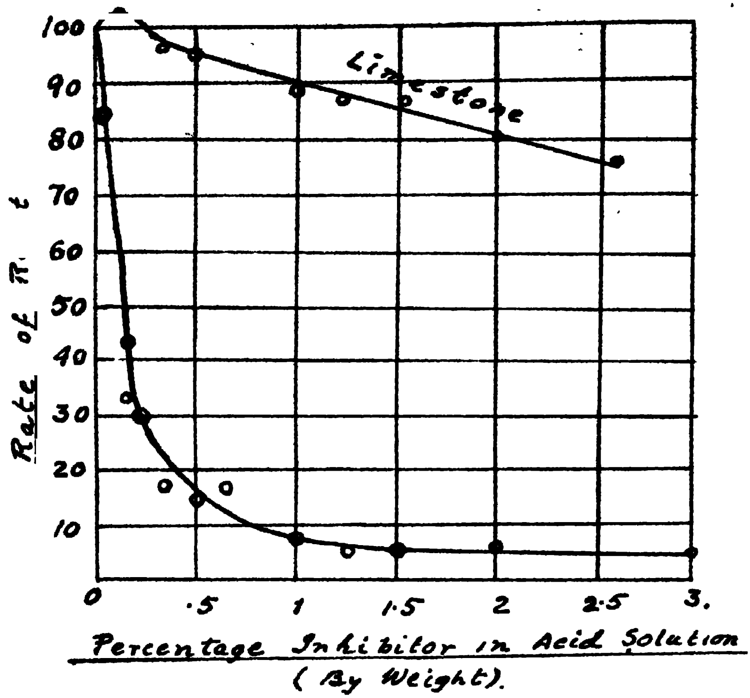
Extensive investigations were carried out in the Mirrlees Laboratory and the results charted out in curves some of which are given on pages 170 & 171. In all the experiments commercial HCl of 1.116 Specific Gravity was used. The rate of reactions was measured by immersing pieces of scale (limestone) and metal, identical in shape and size, in acid solutions of different strengths and then determining the loss in weight of each sample immersed. Period of immersion for scale was kept ¼ hour and for metal 48 hours.

It will be clear from Figure 1 that the addition of 1% Inhibitor has a very marked effect in retarding the action of the acid on cast iron, while only slightly effecting its action on scale.

The necessity of periodical inspections of the water spaces for accumulations of mud and scale cannot be too strongly emphasized. Scale must not be allowed to build up except to a degree suitable for chipping or acid washing.

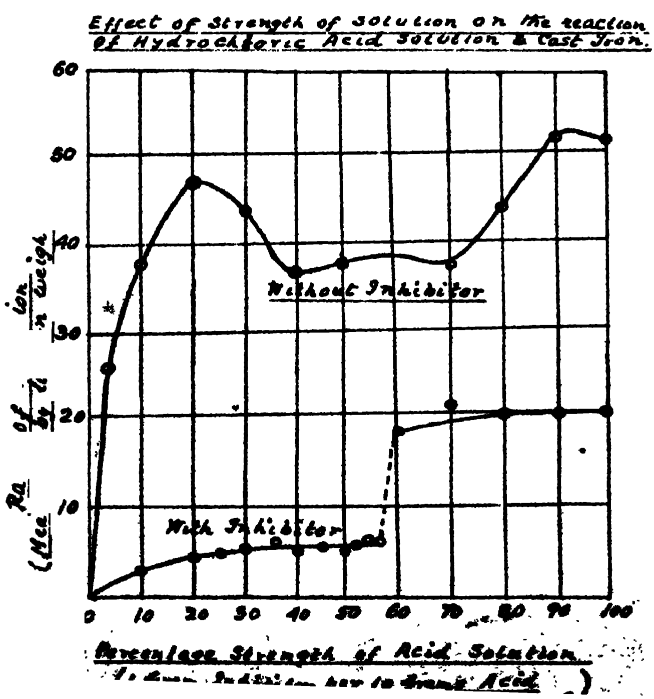
Muddy waters. Where a river having dirty water or a village pond is the only supply, the cooling water should be properly settled and strained before use. Suitable settling tanks and strainers should be designed and put up to stop sludge and slimy matter getting inside the water spaces and choking them up. A case was reported once where the engine which had been in use for 11 months only developed a serious knock. On examination it was found that excessive liner wear had taken place during the period, and the water spaces were choked with mud, fungus and leaves, etc. The liners were changed, water spaces cleaned and arrangements were made to make the water cleaner. The results were extremely gratifying, as the liners did not require renewal again till after a satisfactory service of more than 7 years.

The example quoted above is only indicative of the extent to which liner wear is attributable to bad cooling conditions. Instances may be multiplied indefinitely and each one of them points unmistakably to the fact that clean soft water goes a long way in maintaining steady running and in keeping down the cost of repairs and overhauls, an item which more often than not figures so notoriously in the annual balance sheet of a Diesel station. Some of the items discussed above may appear to be quite unimportant and very commonplace, but it should be realized that it is the elimination and understanding of these very minor troubles which is the quintessence of reduced working costs.



Limestone
100
90
80
70
60
50
40
30
20
10
0
·5
1
1·5
2
2·5
3.
Percentage Inhibitor in Acid Solution
(By Weight).

Fig. 1.



Effect of Strength of Solution on the reaction of Hydrochloric Acid Solution & Cast Iron.
60
50
40
30
20
10
Without Inhibitor
With Inhibitor
0
10
20
30
40
50
60
70
80
90
100
Percentage Strength of Acid Solution

Fig. 2.

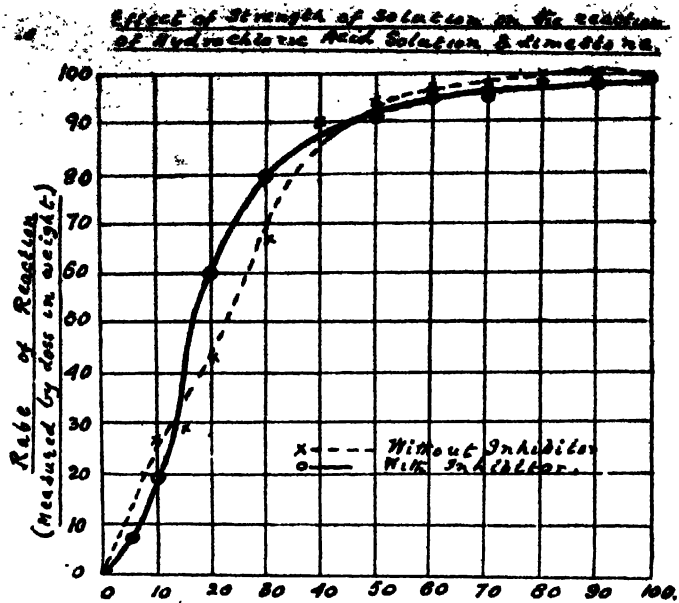


Fig. 3.

Percentage Strength of Acid Solution
(1 gram. of Inhibitor per 10 Grams. Acid
Duration of Experiments:—½ Hour

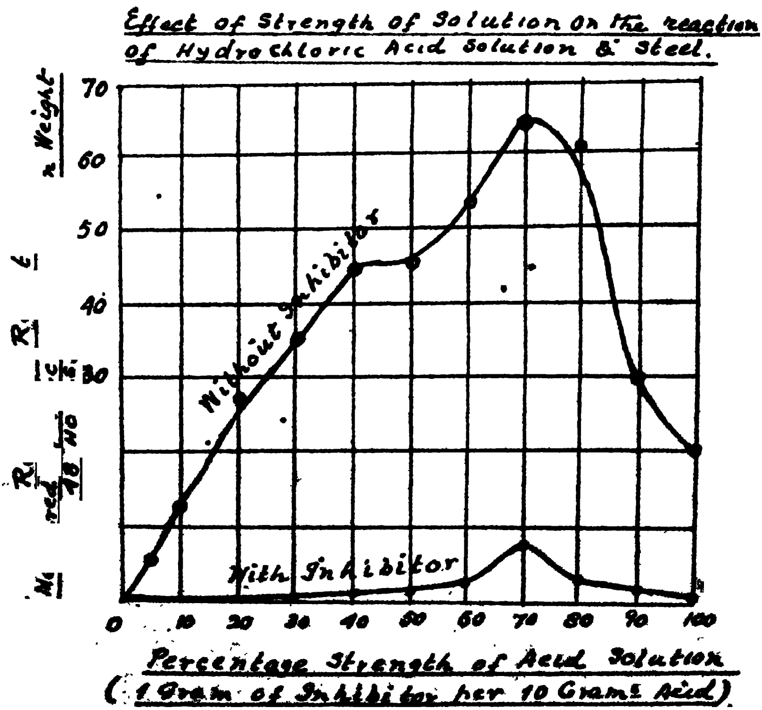


Fig. 4.

DISCUSSION ON
COOLING WATER FOR DIESEL ENGINES.

Col. F. C. Temple remarked that the author was to be congratulated on having put into a compact and easily intelligible form a number of practical rules for the care of the cooling systems of Diesel engines. There were a few points on which some more information would be valuable. (1) The possibility and desirability of using (a) excess lime treatment for a water highly charged with CO_2; (b) a lime treatment as a preliminary to a Zeolite base exchange process. (2) How to safeguard against corrosion with a water reduced by Zeolite to zero hardness. (3) The use of acid as a preliminary to settling colloidal silt out of muddy water which would not clear by mere unaided settlement. Recent information suggested that the preference expressed for natural zeolite or greensand as compared with artificial or gel zeolite might need to be reconsidered. The average softening capacity of greensand was about 3000 grains of hardness per cubic foot: that of good gel zeolite from 9000 to 12,000. That reduced the necessary size of the container by more than 50 per cent. The salt consumption for regenerating greensand was 0·5 pound salt per 1000 grains of hardness removed. Gel zeolite now required only 0·35 or even 0·30 pound per 1000 grains. The wash water requirements with an efficient gel zeolite plant were usually only 25% to 30% of an equal capacity greensand plant. The loss of head through a greensand plant softening 3 gallons per square foot per minute began at about 2 lbs. and rose at the end of an 8 hour run to 6 lbs. The corresponding losses of head in a good gel zeolite plant were ½ lb. at the beginning to 1 lb. at the end. Against all this must be set off the presumed though no longer certain longer life of a greensand than a gel zeolite bed and the greater resistance of greensand to destruction by low hardness (6 to 7 grains) waters.

Mr. J. Malley remarked that the author had dealt fairly fully with the subject and there was very little that one could say to augment the paper. On pages 158 and 159 however, the author gave an analysis of tube well water, and as a point of interest it might be worth comparing the figures for permanent and temporary hardness given by the author, with the figures obtained on a sample of Hooghly water which the speaker had analysed several years ago.

Mr. J. Malley.

Before the water was sent for analysis it was properly settled. The analysis showed the following result:—

Total hardness	22·70
Permanent hardness	4·75
Temporary hardness	17·95

He might, of course, say that that particular sample was taken from the river about the month of March and the result of analysis at any other time of the year would be quite different. However, the permanent hardness of the Hooghly water was practically the same as that of the tube well water mentioned by the author, although the temporary hardness was considerably less. He then narrated the following different methods adopted in the Calcutta district itself for cooling Diesel engines manufactured by Mirrlees, Bickerton and Day Ltd.

(i) At the I. G. N. Dockyard where there were four engines working, the cooling water was drawn from the river Hooghly, passed through a Jewel filter and then taken to an overhead tank.

(ii) Some years ago he supplied to the Calcutta Port Commissioners a Diesel engine and pumps which were fitted on a Jet dredger, the function of the one being to pump water through a jet in order to blow away silt which collected in in convenient places on the river, as for example under the Pontoons of the Howrah Bridge on the Calcutta side and under some of the landing stages on the river. As one could readily understand, he did not want to pump raw Hooghly water through the engine jackets, so to overcome the difficulty he arranged that the engines would be cooled by clean soft water which in its turn would be cooled by the large volume of river water being pumped by the main pumps. Storage tanks for the soft water were provided on the Dredger and the water from these tanks circulated through the engine jackets and then passed through the tubes of a tubular cooler, the raw water passing on the outside of the tubes. By that method the fresh water was used over and over again and very little make-up was required.

(iii) A very similar arrangement was adopted in the case of the engines supplied to the Bhatpara Sewage Scheme, but in that case he used the raw sewage as the cooling medium for the fresh soft water and a cooler with specially large bore tubes was provided to prevent any possibility of choking. In that case, the sewage passed through the tubes. In items ii and iii it was hardly necessary,

where clean soft water was used, to run the water through the jackets for a long period after the engines had been stopped, but the system was recommended where there was doubt about the hardness of the water.

As regards the green moss on open cooling systems mentioned by the author, originally the water storage tank on the roof at Bhatpara was an open tank and he had this trouble with green moss growing in the tank, but when a cover had been put on the tank the trouble had been overcome.

On page 167 the author illustrated a type of Liner Drawing Gear. A year or two ago Mirrless, Bickerton and Day devised another type of drawing gear which was probably more effective than any others which he had seen. It was a little bit difficult to illustrate without a drawing, but it consisted of a circular steel flange with holes in it having the same pitch as the cylinder cover studs, while a small circular steel flange was used at the bottom end of the liner in a similar way to that mentioned by the author. Four long bolts of about $1\frac{1}{4}''$ diameter passed through both flanges, the top flange having been placed on the cylinder cover studs, the nuts of which were on the underside of the flange and were used as jacks to force the flange upwards. After the initial jacking given by the nuts on the cylinder cover studs, the process was continued by screwing up the nuts on the four long bolts which passed right through both flanges.

In regard to the Mirrlees Inhibitor mentioned by the author and the curves reproduced by him, illustrating the experiments which were carried out by Messrs. Mirrlees, Bickerton & Day Ltd., Mr. Malley remarked that the inhibitor was not a new idea. The trouble in the past had been that most of the inhibitors discovered and used for inhibiting the action of hydro-chloric acid on metals, were too expensive for commercial use. So Mirrlees' Works set about investigating the matter and experimented for over a year with various materials, until they eventually discovered a material which diminished the action of hydro-chloric acid on metals and could be supplied at a comparatively reasonable price. This was the inhibitor which was described by the author and which had been used successfully in many installations.

Mr. C. Warren Boulton asked for an explanation of the statement on page 162 to the effect that if the outlet water from the engines was allowed to run to waste hard water would leave no noticeable scale, whereas if the same water was used over and over again considerable wear would take place. He presumed

that what the author meant to infer was that, provided a constant flow of water was obtainable, the question of hardness did not matter seriously as the temperature of the cooling water would not rise appreciably but as no mention of the temperature was made by the author some explanation of that point was advisable. Mr. C. Warren Boulton.

Mr. W. J. Nicoll remarked that the paper was one which would no doubt give Diesel engine users some food for thought as it dealt with a subject which, in his opinion, received far too little attention in India. The scarcity of water in many parts of India where there were Diesel engines necessitated the economic use of the water available. Mr. Goverdhan had dealt very effectively with the cause of scale formation in water jackets, etc., and also suggested several useful remedies to prevent this. Softening of hard water by evaporation would appear to be a very effective and efficient method as sufficient heat could usually be recovered from the exhaust gases for the purpose of distilling the make-up water requirements. Although that method had not apparently found favour in India, there seemed no reason why it should not be adopted where clean soft water was scarce. With regard to the filtration of river water for make-up purposes, this could be very effectively carried out by a modern filter such as a "Jewel." The necessary care did not end in filtering the make-up water, however, but precautions must also be taken against dust entering the cooling tower and ultimately being picked up by the water. If air was circulated by means of a fan, the former should be drawn through an air filter screen, and in a dusty area the tanks should be covered and provided with efficient ventilators. The tanks should also be fitted with baffle walls in order to assist in the precipitation of solids and the speed of the water should be as slow as possible to eliminate turbulence which might cause any agitation of the sediment in the bottom of the tank. A wooden or asbestos roof provided an excellent cover for a cooling tank because of their heat non-conductive properties which assisted in reducing the losses due to evaporation. Modern engines were provided with water jacket inspection doors, and in the case of a vertical engine the removal of mud was a comparatively simple process. This was not so in the case of the cylinder head as it was generally necessary to remove the latter to clean it thoroughly. It had been found that when an outlet water pipe was inserted below the level of the inside of the cylinder head jacket, scale had been deposited in excess due no doubt to overheating caused by an air lock or steam pocket being Mr. W. J. Nicoll.

formed in the jacket. It was, therefore, essential that the water outlet should be at the highest point of the cylinder head and that the open end of the outlet pipe should be above the cylinder to eliminate syphoning. Where return pipes were brought down below the level of the cylinder, a vent pipe should be provided at the highest point of the system. As a final precaution against scale forming in excess, it was advisable to draw all liners for inspection after about 10/15,000 hours, especially where the water was hard or of a high muddy content, as some inaccessible part of the jacket which had not been properly cleaned out might not only result in forming 'hot spots' in the liner, but a distortion of same causing piston seizure and probably the fracturing of the water jacket. Mr. Goverdhan correctly mentioned that low outlet water temperature did not necessarily indicate that the liner temperature was low, when it was remembered that a 1/16" layer of Ca. and Mg. salts had approximately the same heat resisting value as 1" of cast iron. This was a point of importance in the successful running of a Diesel engine. It was a general practice to run engines as cool as the cooling system would permit, i.e., to reduce the temperature of the cylinders to the minimum. In order to retain the cylinders of a Diesel engine at a low temperature, much useful heat was carried off by the cooling water, and the efficiency of the engine considerably reduced thereby. Chilling of the cylinder walls tended to liquefy the fuel as it was injected into the cylinder with the result that the fuel was not only wasted due to incomplete combustion, but it destroyed the oil film and ultimately found its way into the sump in the case of a vertical engine, and diluted the lubricating oil. It had also been proved in some cases that the liner wear was actually greater when the liners were cooler than when at a reasonably high temperature, better distribution of the oil being maintained under the latter conditions. Assuming that the water jackets were clean and that the liners were free from scale, the outlet water temperature should be between 120°F. and 130°F. Provision should be made to keep the temperature within these limits even with an increase in load. Although in modern high speed Diesel engines this temperature might be exceeded, it did not necessarily indicate that the internal surface of the cylinder was overheated. The high cooling water temperature in these engines was principally due to the fact that the cylinder walls were much thinner, there were more explosions per minute and the quantity of water in circulation was less than in the case of heavy Diesel engines. The outlet water of a high speed Diesel might be as high as 180/190°F. without impairing the efficiency of the engine. The temperature of the exhaust gases was in many instances a better indication of the cylinder

wall temperature than the cooling water. In conclusion, he congratulated the author on his Paper as it contained some very useful information for Diesel engine users. Mr. W. J. Nicoll.

Mr. E. F. White remarked that it was pleasing to note that Mr. Goverdhan had raised the important subject of arranging for a suitable supply of cooling water for Oil Engines. Having correctly installed the engine and filled up with fuel and lubricant, users were inclined to sit back thinking all that could be expected of them for the engine's welfare had been done. Further thought must be given, however, as to the purity of the cooling water to be used and its exit temperature. A supply of soft water, preferably rain, might be arranged for but, in the speaker's opinion, the kind of water to be used was not so important compared with the use of an adequate quantity so that the temperature of water leaving the cylinder heads be kept within, say, 120 degrees F. or 49 degrees C. Any water which was not quite soft deposited its minerals at temperatures of 125 to 130 degrees F. upwards. It was important therefore that excessive outlet temperatures were not reached. When, owing to high temperatures, mineral deposits were known to exist in the water Jackets, a proprietory softener known as "DM" Boiler Enamel might be used. Owing to the action of the enamel upon existing scale it was found that deposits would flake off and might lodge in water tubes or other confined spaces. This required watching if water ways were not to be blocked by scale. Messrs. Petters Ltd., had made extensive experiments with scale solvents and had obtained good results from a preparation known as "Clensol." To use that preparation cylinder heads were removed and inverted with the then bottom water-way plugged. The Head was then filled with Clensol, neat, of the strength in which it was supplied and left for a period of 3 or 4 hours. The effervescent action of the solvent upon scale deposits appeared to dissipate the latter for very little sludge remained to be washed out and the metal would be left clean as new. For cleaning Cylinder Jackets which were not usually so thickly coated with scale compared with cylinder heads, a mixture of 50% each Clensol and water would be found effective. The use of that solvent was much quicker and more efficient compared with chipping. Dilute hydrochloric acid (15 to 20% HCl) was also a good solvent but required greater care in the way of washing out. For Indian conditions probably the best method of dealing with cooling water (if same was to be kept at or about 120 degrees F. to avoid precipitation of minerals in cylinder heads) was to employ a cooling tower, or spray cooler. If a "run through" system of cooling water could be arranged at sites where Mr. E. F. White.

there was a plentiful supply, the water should pass from the bottom of cylinders up through the top of cylinder heads, thereby entirely filling the Jackets to the exclusion of air pockets. In reply to a question by Mr. Nicoll the speaker stated that assuming water Jacket temperatures of about 120 degrees F. were arranged for, the cylinder liners and pistons would have temperatures about correct for fuel consumption efficiency whilst viscosity of lubricating oils would not be impaired as would be the case if working under excessive heat. A further objection to excessive cylinder heat lay in the abnormal expansion of Jackets and Liners and possible difficulty with the joint between those 2 parts.

In reply to the various points raised by Col. F. C. Temple the author said that with regard to the first point viz. the possibility and desirability of using excess lime treatment for water highly charged with CO_2, that was very desirable and would have the double effect to removing the excess free carbonic acid and eliminating the temporary hardness by precipitating the lime present in the form of bicarbonates. Thus,

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

$$Ca(OH)_2 + Ca(HCO_3)_2 = 2CaCO_3 + 2H_2O.$$

If the amount of permanent hardness was small, say 3° or 4 degrees only, no further treatment might be done to make the water suitable for engine cooling.

As regards the second point viz. the possibility and desirability of using a lime treatment as a preliminary to a Zeolite base exchange process, he said that that might be done in case the CO_2 contents of the water was pretty high, to prevent the free acid from attacking the Zeolite and thus reducing its useful life, in the first instance, and subsequently to avoid corrosion and pitting of the Jackets, etc. In practice, however, the double process of lime treatment and base exchange softening were likely to be less convenient than a direct lime-soda treatment which should be preferable to the Zeolite process in the presence of excess CO_2.

In regard to the third point viz. how to safeguard against corrosion with a water reduced by Zeolite to zero hardness, he said that in cases where fight against corrosion became a necessity, the causes of corrosion should be investigated first. These might be as follows :—

(a) Gases dissolved in water like CO_2 and oxygen. These might be present in the water as it came out from the source, or

might be absorbed from the atmosphere in the case of an open storage tank or sump. The Author

(b) Presence of acids in the source or from external pollution.

(c) Presence of corosive minerals like magnesium chloride, Alumino Ferric, etc. These causes of corrosion in iron or steel were generally always aided by chemical and electrolytic action specially in the proximity of copper, gun metal, or brass fittings. In general carbonic acid and air dissolved in water were a very common cause of corrosion, the former re-acting with iron or steel to form ferric acid and resulting in pitting. Calcium hydrate or slaked lime should be used to neutralize the acidity due to CO_2 present in the water as it came from its source.

When absorption of acid fumes from a foul atmosphere was the cause, arrangements to cover up the exposed portions of the cooling system should be made as far as possible. The presence of corrosive minerals would indicate complete neutralization of the water with soda treatment. Notwithstanding the above safeguards, corrosion might still be traced to the dissolved air which it was hardly possible to eliminate altogether from the system. Against this it would be a wise precaution to paint the internal surfaces of the water Jackets, cylinder heads, pumps and auxiliaries exposed to the risk with suitable anti-corrosion paints, so far as time and conditions of working permitted such a procedure to be put into practice. Suitable anti-corrosion paints like "Apexior" etc., were on the market and might be made use of, although that method if wholly relied upon was likely to lead to the formation of localized weak spots inaccessible to the paint, but suitable for the development of air locks or steam pockets.

(3) As regards the fourth point viz. the use of acid as a preliminary to settling colloidal silt out of muddy water, which would not clear by mere unaided treatment, he said that colloidal silt was not very commonly met with except in cases where the only supply of water was from a river in flood or during the monsoons. And since conditions as above obtained only for short periods it would be more advisable to make use of the water after removing the major impurities amenable to settling, rather than rendering the entire supply acid and therefore undesirable from the Diesel Engineer's point of view. Any mud and sludge that collected in the water spaces could be easily washed away when the purity of the source of supply returned to normal. It was written in the Chemistry of Colloids that particles of silt carried negative ions and if these were neutralized by the addition of positive ions to the

thor solution, the silt would precipitate. Although sulphuric acid was very suitable for supplying positive ions its introduction into the cooling system was not desirable from the author's point of view. In fact the aim should be the neutralization of any acidity already present in the water rather than the addition of it.

He felt much obliged to Colonel Temple for drawing attention to a few very important or rather vital issues on the subject and had to thank him for giving him an opportunity of making the paper more comprehensive and lucid on certain points.

In reply to the comments of Mr. J. Malley the author said that the analysis of the Hooghly water given by Mr. Malley was quite interesting and as coming from a river the water was not so suitable for cooling purposes as might be expected. He might mention that for Power Stations and other purposes where large quantities of cooling water were required, it would be convenient and advisable to install suitable motor driven centrifugal strainers for dealing with the type of impurities carried by river waters. The liner drawing gear described by Mr. Malley was a good variety. The description given, however, appeared to be defective somewhere, as since the top flange had threaded holes of the same pitch as cylinder cover studs it would not be possible to seat the flange through the cylinder studs on to the nuts unless Mr. Malley used the word 'pitch' to designate the 'diameter' of the studs. In his opinion the holes in the top flange were meant to be just plain holes of the same diameter as the cylinder studs in which case he could easily seat the flange on the nuts and use them for jacking up the liner, which was perhaps what Mr. Malley was driving at. Also to make the gear simpler it would be better to use a single or just a couple of central bolts only as the manufacture and manipulation of a gear with four long 1¼" diameter bolts, which would have to be threaded a good part of their length, were more complex than in the case of devices needing only one or at the most two central bolts.

In reply to the comments of Mr. C. Warren Boulton he said that Mr. C. Warren-Boulton had evidently misapprehended the statement that "if the outlet water from the engines was allowed to run to waste hard water would leave no noticeable scale, whereas if the same water was used over and over again considerable wear would take place." It was not because there was the possibility of the outlet water temperatures going much higher through repeated circulations that the risk of excessive scale deposits had to be faced. In fact, the circulating water temperature having attained a constant value, depending

upon the season of course higher in summer than in winter, the outlet water temperatures were not allowed to fluctuate much except between the limits of 120°F. to 140°F. It was, therefore, not because the cooling water temperature was kept much lower by having a fresh supply of water running through all the while that the advantage was gained. The advantage lay in avoiding concentration through evaporation. Repeated circulation of the same volume of water increased the concentration of the salts in solution and that meant a constantly increasing degree of hardness. Analysis of water which had been in use for some considerable time would indicate a degree of hardness far in excess of that of fresh water and knowing that a saturated solution might carry as much as 150% or more of a solid impurity by weight in solution before precipitation, the tendency to heavy scaling might well be appreciated. The importance of this was hardly realized by engine users in practice. The Author

Replying to the comments of Mr. W. J. Nicoll the author said that Mr. Nicoll had stressed certain very salient features in connection with the cooling systems and this deserved appreciation. Not much note was taken of those important factors by a majority of Diesel Engine users in India who appeared to be guided by the age old expression—"if ignorance is bliss it is folly to be wise," although ignorance was a doubtful bliss in most cases and certainly inconvenient and risky where Diesel Engines were concerned. Sooner or later they found themselves in the unenviable position of the purchaser of the second hand car who when asked by the dealer, the next day, as to how the car was functioning, replied, "O, well everything makes a noise except the horn." With regard to the practice of running the engines as cool as possible it was true that the working efficiency was lowered, but that this contributed to greater liner wear might have to be reconsidered. If the cooler parts of the liner were subject to uneven lubrication and greater wear, the diameter measurements of a liner which had been in use for sometime, would show a progressive increase as micrometered from top downwards, a fact quite contrary, however, to the Author's experience and observation. He was inclined to think that in cases, as reported by Mr. Nicoll, where liner wear had been observed to be actually greater when the liner was comparatively cooler, use was made of a cylinder lubricant that offered high resistance to even distribution at the lower temperatures, more generally obtained in actual practice, and spread more evenly when thinned down by the high temperatures corresponding to full or overload conditions. Such an oil could hardly be considered as

a suitable lubricant for the engine and one striking a happy medium would be more correct. That it was essential for a lubricating oil to be able to maintain its viscosity and easy spreading quality between a fairly wide range could be well realized when it was considered that the exhaust temperatures of individual cylinders might vary from about 300°F. at low loads to about 800°F. or more at high loads.

Replying to the comments of Mr. E. F. White the author said that Mr. White recommended "Clensol" as a suitable scale solvent and there was no reason why the engine users should not give it a trial. The author had tried similar preparations, one of them known as "Starrett" or something to that effect with good results.

In conclusion, the author felt much gratified to note the interest shown by various members and thanked them for the encouraging and interesting comments made.

THE POSSIBILITY OF FLOOD REGULATION AND CONSERVATION IN THE HIMALAYAS FOR IRRIGATION OR POWER.

BY

J. W. MEARES, Member.

> may have shown the engineer a solution of a great problem; as been done naturally, without design or control, can surely man with calculation of the effect" (Triennial Report of the tric Survey of India, p. 29). "Credo quia absurdum"; certum est quia impossibile." (Tertullian).

India, more than any country in the world, depends upon water for her life, and from prehistoric times she has exploited it both for irrigation on a large scale and for local power on a minute scale. Both reservoirs and canals were constructed long before the beginning of the British Raj. At the present time, the vast canal systems of Northern India are using a considerable proportion of the total water that arrives at their headworks during the irrigation seasons; but there are times when much more could be used if it were available. It was natural that engineers should turn to the source of all this water in the Himalayas, in order to see if conservation in the upper reaches of the snow-fed rivers might be possible; for, at times when it is not required, a great volume passes to the sea. The Indian Irrigation Commission of 1901-03 estimated that of the total average rainfall (37½ inches), 35 per cent is carried away to the sea, while 6 per cent is used in irrigation, the remainder being absorbed or evaporated. Alive to the great waste, the question of storage was considered; but authoritative opinion (referred to presently) held that it was not an economic proposition. To challenge such a pronouncement requires some courage, but this paper is nevertheless a plea for further consideration, on somewhat novel lines, in view of the importance of the issue. If every dogmatic assertion of even the greatest men had always been accepted as final and irrevocable, present day conditions would be very different from what they are.

In the course of his report on the water power resources of India, *the author of this paper threw out the suggestion, now

* Triennial Report of the Hydro-electric Survey of India (1922), para 33; see also letter to "The Times" (London) July 19th, 1932.

put forward in greater detail, for a somewhat revolutionary method of flood regulation and storage in the upper waters of the great Himalayan rivers. At the time this attracted little or no notice; but in view of certain equally novel proposals, referred to presently, in connection with the Severn barrage, the matter now appears worthy of serious discussion.

HIMALAYAN STORAGE CONSIDERED IMPRACTICABLE.

Briefly, in order to show what the ensuing discussion leads up to, the proposal is to make storage lakes on a very large scale by means of hydraulic-fill or blasted earthen dams of great length and height, such as have been fortuitously made by natural landslips, with bye pass tunnels of sufficient capacity to prevent any possibility of a dam being topped and destroyed by flood.

Wherever rivers arise in mountainous country, their development either for irrigation or power or both must become important, though so far as irrigation is concerned this only applies to tropical and sub tropical regions. Fuel at present, despite the great increase in its cost in recent years, still holds its own in most countries for power generation; but this will not always be so, and the margin even now is not very great. Any storage and regulation of water for irrigation may, in the future be of value for power, so that aspect of the problem need not be considered further. What applies more particularly to the Himalayan rivers of the Punjab and the United Provinces, in view of the irrigation systems fed by them, will sooner or later apply to many other areas where there are mountains, and particularly snow-fed mountains. As the snows melt, huge quantities of water pour down into the plains and for the most part, as already mentioned, flow to the sea unused. The value of this water to dry regions at present unirrigated (including areas out of command of the canals, which require a pumped supply) would be inestimable; it might be calculable, though it would be fair to call it incalculable. The desirability of storage in the Himalayas was recognized as far back as the 'sixties. The matter came before the Indian Irrigation Commission, but Sir Thomas Higham* "did not consider it worth while to investigate the Himalayas for storage," an opinion which also one of his predecessors had recorded. Here the matter has rested. The absence of any famine over northern India in recent years cannot be taken as proof that another will never come, despite all the beneficent works (including the Triple Canal, the Sarda canal

* Sir Thomas Ward. Procdgs. Inst C. E., Vol. 233, p. 161.

and the Sukkur barrage) that arose from the last. When this catastrophe does come, the urgent necessity for further protective works will at once be pressed, since it is well known that the supplies in the Jumna and the Sutlej (at least) are not sufficient to irrigate the whole of the land available; and that there are tracts on both rivers without protection, as well as large areas of irrigated land that are insufficiently protected in years of low river supply.

DAMS IN GENERAL.

High dams have been the subject of much controversy, and a Commission (emanating from the World Power Congress) has been investigating the subject for some years. It may safely be said that he would be a bold man who dared to suggest either a gravity or an arched dam, in a locality where earthquakes occur, of more than about 500 feet height. That was the suggested height of the Bhakra dam on the Sutlej, the design being of the orthodox type. It remains a paper project, though it will unquestionably have to be carried out presently—after the next famine. India, however, like many other countries, has a number of great masonry dams which have been built for impounding excess rainfall for subsequent use in irrigation; while dams for power alone are to be found everywhere and occasionally the two are combined. Generally the distance between storage and point of use is comparatively small, but there is no reason why this should be so except when the object is power, in which case the extra head of the dam, or some of it, is employed.

THE SEVERN BARRAGE SCHEME.

A feature of all such dams, whether of gravity or arched construction, is that they are necessarily built rigidly watertight; leakage through or round them, and especially under their foundations, has been the cause of many disasters of the first magnitude. Physical difficulties may, however, make the construction of a watertight dam impossible, and yet the river can be effectively blocked.

Such a case has been met with in the estuary of the River Severn, and the recently issued Report of the Severn Barrage Committee* incorporates a proposal for closing the tidal "Shoots" (a deep and rapidly flowing channel) which departs altogether from current practice and may have far-reaching con-

* H. M. Stationery Office, 1933. Appendixes.

sequences. Here the construction of a dam, either of masonry or concrete, would obviously be impossible:

"Anything in the nature of solid blockwork would be out of the question, owing to the impossibility of setting blocks in such a tideway. It would be equally impracticable to close the channel by tipping a rubble bank from one or both ends of the dam, since, as the opening narrowed, the velocities of the tidal stream would be increased so as to render futile any further deposit of stone. In the consulting engineers' opinion, the most satisfactory solution would be to bring up the work in more or less even layers extending across the waterway, thus gradually forcing more and more of the ebb and flood stream through the sluice dam openings. To this end, they propose that the embankment dam should be constructed by depositing two banks across the channel. Of these, one would be for the upstream face of the embankment (which would be undertaken first), and the other for the downstream face. The space between the banks would be filled with suitable material so as to form an approximately watertight core. Some difficulty might be experienced in depositing the lowest layers, resting on the clean bed of the channel, but once these had been satisfactorily stabilized, the rest of the work should present no special difficulty." (Report, para 188).

For the filling, sand is suggested. The main point to which attention is drawn is the use of a sand filling to give "an approximately watertight core," instead of the rigidly watertight type of dam that is usually insisted upon and generally necessary. So long as the embankment is in no danger of being washed away, a certain amount of percolation through it is here of no moment; though it is anticipated that there will, in fact, be very little. In order to ensure stability, the two initial banks are to be placed from 500 to 1,000 feet apart, the intervening space being filled in by sand.

NATURAL DAMS AND LAKES.

Now this method of embankment, though novel and daring in engineering, is literally "as old as the hills." Hundreds of permanent lakes exist which were initially formed by the damming of a gorge or a narrow valley by a great landslide, and many more temporary lakes of enormous extent have been similarly formed and eventually washed away wholly or in part when topped by a flood. A well-known instance is the Gohna Lake, to the north of Naini Tal, of which a considerable part has remained from 1893 to the present day, though every year reduces its area and capacity. Still better known, owing to the stories it gave rise to, is the dam which was formed in a gorge of the Indus, in the remote Gilgit district:—

"In December 1840 a side of the hill known as Hatu Pir fell into the defile of the Indus at the base of Nanga Parbat, and formed a dam 1,000 feet high. An immense lake was created behind the dam, the water in which became at one place 900 feet deep; at Bunji the

water rose to the level of the fort, 300 feet above the bed of the river; the lake became nearly 40 miles long and reached almost to Gilgit town. For six months the waters were held back by the debris of the fallen mountain, till they rose to the level of the top of the dam. The dam then burst, and the lake emptied in one day, the immense volume of water rushing down to Attock."*

EARTHEN DAMS AND ROCK-FILLED DAMS.

Let us now turn to earthen dams, including hydraulic-fill and rock-filled dams. These have been used since the dawn of civilization, and, despite their rough and ready design and construction, often lasted for generations. Modern earthen dams, with a puddle or other core, are frequently used at the present day; the other two types are a more modern innovation, and have been extensively used in America. As bearing on the present paper, and showing the capabilities of hydraulic sluicing, the author may mention that in 1907, at Seattle (U.S.A.), he saw a very considerable hill being entirely demolished by this method, the debris being used for the reclamation of land in Puget Sound. Six inch electrically-operated high-pressure water jets were employed for the purpose, wooden flumes conveying the spoil to the shore. The same procedure is adopted for making dams.

The various types of earth and rock dams have a literature of their own,* as well as an abundance of technical papers which need not be enumerated here. As indicating the present limits of these forms, it is worthy of note that, although high dams are often mentioned in these works, there is no record of any of a height approaching that of masonry dams; the limit so far appears to be of the order of a hundred feet or so,* and most of those constructed are far lower. A project was prepared by Mr. Woods (of the Punjab Irrigation Department) for an earth dam reservoir on a large scale, at Kodi on the Jumna, so long ago as 1912; trial borings and preliminaries were carried out, when the war broke out and caused a cessation of this and many other works.

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* Burrard and Hayden. "The Geography and Geology of the Himalaya Mountains and Tibet", Part III, p. 177; on the authority of Col. Montgomery.

* Jas. D. Schuyler. "Reservoirs for Irrigation, Water Power and Domestic Supply."

E. Weyman. "The design and construction of Dams."

W. L. Strange. "Indian Storage Reservoirs with Earthen Dams."

B. Bessel. "Earth Dams."

* The highest earth dam appears to be that of San Leandro, California, viz.: 125 feet.

The ever-present danger of the water topping the dam, and causing its instant destruction, is no doubt the main reason for keeping to a moderate height. The difficulty of providing a sufficient spillway is often great, and in any case it must be at the top, so that no storage capacity is behind it to help in absorbing abnormal floods; the tunnel diversion method shows the only safe solution.

BYE-PASS TUNNELS FOR DIVERSION OF RIVERS.

It would seem to be almost certain that the haphazard landslip dams referred to above would in course of time have formed permanent lakes to their full height (nearly) if they had not been topped by floods. It is also clear that a bye pass tunnel through the cliffs, of sufficient cross section and at a suitable height—far below the top—would effectually have prevented this destructive topping. This is the construction which, it is suggested, might be made use of.

The bye passing of a river through tunnels is no novelty. Apart from the great use of tunnels in modern hydro-electric practice, as on the various Bombay works and on the Uhl River in the Punjab, where they act as carriers of the power supply, they have also been used in the way now suggested. During the construction of the Hoover dam, of the Boulder Canyon project in America, the river was diverted through four fifty-foot tunnels each 1,000 feet long, before the foundations of the 750-foot arched concrete dam could be put in, the flood discharge being some 250,000 cusecs flowing at 30 miles per hour.* Here, so far as the diversion problem is concerned, is practical demonstration that the method is feasible on a magnitude, both of cost and of water volume, comparable with that of the Himalayan rivers. The use of a side tunnel as a bye pass is mentioned by Weyman and urged by Bessel (*op. cit*), so is far from being a novel and rash experiment; but it has not been used as a *permanent* safeguard for an earthen dam of great height.

CONDITIONS IN THE HIMALAYAN RIVERS.

Most of the Himalayan rivers have a comparatively gentle slope in their upper reaches, where of course their discharge is also reasonable. Thus the slope of the Indus from its source to the base of the mountains averages only 15 feet to the mile, while "over a considerable length of its course in Tibet, the fall is hardly more than 3 feet a mile." (Burrard and Hayden, *op. cit.*,

* *Electrical Review*, June 23, 1933, p. 902.

p.171). The capacity of the landslip lake referred to above must therefore have been very large. In catastrophic circumstances such as the bursting of the dam, nothing can be done except wait for the flood and arrange for warnings to be sent down, as was done. It is not possible to prevent the bursting of such a natural barrage; but it certainly is possible to form an artificial lake on the same lines in a suitable gorge, making arrangements beforehand, by tunnelling a bye-pass, so that the dam can in no circumstances be topped. The matter is simply an economic one of outlay and return on outlay, if it were to be reckoned a "productive work";* but it could be a "protective work" from the famine point of view, which would then resolve itself into a matter of how much loss could wisely be incurred. As pointed out above, a spillway would offer no security.

METHOD OF CONSTRUCTION SUGGESTED.

The construction of such a work as has been outlined above, in a remote and rather inaccessible region, would present many difficulties; but it is the engineer's business to overcome difficulties. The problem is to construct an earthen dam of the greatest possible height in the most inexpensive way consistent with its ultimate safety; and the difficulty arises mainly in the early stages, when a flood may destroy what has been already done. This early and most exacting part has parallels in many existing Indian irrigation works.

It is clear that before any beginning could be made on the barrage itself, both the upper (permanent) and lower (construction) bye-pass tunnels would have to be complete in every respect; their order of construction would be immaterial, except that the upper one would be entirely secure from damage in all circumstances, while the lower one would be more vulnerable.

The lower or construction bye-pass tunnel would be at about bed level, its function being to divert the river during the formation of the barrage up to the height of the permanent bye-pass; it would in any case be silted up in course of time, but it would not form part of the permanent works and could be blocked at the mouth when done with. The authorities agree that a pipe through the dam itself would be unsafe; even if bedded on a rigid wall.* This temporary bye-pass would have to be capable of carrying nearly the whole flood discharge of the river; not the

* These are Indian famine terms for irrigation works.

* Weyman; Bessel. *Op. cit.*

whole, because by choosing the right time for beginning work on the dam, it would be possible to have considerable storage room behind it in time for the following flood season.

Coming now to the permanent high-level bye-pass tunnel, the main problem of calculation would be the determination of its capacity.* Allowing for the storage capabilities of the site, this would depend upon the height of the entrance above bed level and on the mean discharge of the river during the period when the snows are melting, or during the monsoon, whichever may be the greater—in the Himalayas, it will be the former. With sufficient storage capacity, the maximum flood discharge (once the barrage is complete) is immaterial. Assume for a moment that the whole work has been made, with the permanent bye-pass comparatively low down and capable of carrying the mean discharge on a nominal head without being wholly submerged; then a heavy flood would cause the lake level to rise, and the tunnel discharge would increase accordingly. Calculation and experiment in the early years would enable the final waterway to be such that the water could never rise to within (say) 15 feet of the crest; and this margin, whatever it might be, would have behind it a huge waterspread extending upstream for a score or more miles.

The main tunnel entrance would be as low down as would be consistent with safety, in view of the silting up of the lake near the dam—probably about 100 feet above base level, more or less according to the slope of the bed; the lowest hundred feet would in any case be useless for storage, and, as the lake filled up, silting would take place further and further upstream. The river would flow through under a comparatively small head after the storage had been mostly used up, just as though there were no barrage; and, as the flow increased with the melting of the snows, the entrance to the tunnel would be submerged more deeply and the discharge progressively increased under the rising head until a balance was attained; the lake behind filling up until flow and discharge were equal at a calculated level below the crest.

Even without regulation, the quantity impounded would last for many months after the discharge of the tunnel exceeded that of the river, assuming the necessary adjustments to have been made in the first off season after completion of the works. But at the

* In all probability at least two permanent tunnels would be used, the second being at considerably greater height above bed level than the first. The lower one would be designed to carry the maximum supply required for the extended irrigation demand, when just submerged, while the upper one would be the flood regulator.

present day. regulation has become a simple matter. It would be done from almost any distance by a two-wire power line and an indicating circuit. Operating power would be available at all times at the site, from the tunnel discharge. Automatic regulation would probably be better still, so long as it worked on the railway system of safety (by full opening under gravity) if the automatic gear failed or were interfered with. The tunnel entrance, at the height suggested, would always have perfectly clear water round it. During the brief period when it is only partly submerged, screens would adequately protect the gate. The entrance would as a matter of course be some distance above the upstream end of the dam, and the exit well below the lower end; it would be advantageous to carry it well into the cliffs, in case blasting were used. A semi-circular bend, such as those occurring on both the Sutlej and the Jumna, would be a very favourable location for such a work.

THE MAIN WORK.

Having completed both bye-passes, the construction of the dam itself would begin. The season would have to be chosen so as to allow the maximum time for the lower part to be completed, so that the combination of the construction tunnel and the storage capacity would safeguard the work during the first flood season. Probably the base of the dam in the direction of the stream would have to be some quarter of a mile in length. Loose boulders would first be dumped at the two extremities, and the falling river would find its way through them, unless a diverting cofferdam were found advisable. Power for the high-pressure pumps and for the transit of materials would be obtained from a temporary hydro-electric plant. As soon as the level of the upper and lower components reached well above that of the construction tunnel, the space between would be filled up either by blasting or by hydraulic sluicing or by both; and this would presently divert the flow through the construction bye-pass. Thereafter the filling up would be a race against time, so as to bring the barrage up as far as possible above the lower bye-pass before the next flood season. This, no doubt, would offer great difficulties in the way of labour; but that would all come into the debit and credit account of the value of the stored water in terms of corn. It would be a critical time, for it is unlikely that the dam could possibly be built in one season up to the height of the permanent bye-pass. When completed to the full height, to which the gorge alone would set a limit—for the value of the flooded land would be negligible—the lower tunnel would be closed by dumping material over the entrance. Leakage through it would not matter, as

it would merely come into the regulation problem. Such a barrage would be unaffected by earthquakes. Again, percolation through the great length of the barrage would be harmless, and would stop after a few years.

Bearing in mind the continual accretion of tributaries, the volume of water to be dealt with would not be unreasonably large. The late Mr. R. B. Buckley records* "extraordinary discharges" of a number of rivers that have long been under observation. The Indus at Sukkur—hundreds of miles from the source—has given 900,000 cusecs; the Ganges at Benares—still more distant from the hills—records 1,285,000 cusecs. Only a small fraction of these discharges would be found in the upper Himalayas at the time of heaviest discharge. Once the work was done, the greatest flood would merely raise the lake level, and the impounded water would be available over a long period in the lower reaches, instead of flowing over the canal waste weirs and being lost.

The difficulties are formidable, but the prize is great. The idea of constructing such an unconstitutional work will doubtless strike most civil engineers with amazement and horror; but it has been done by nature and can be repeated by man.

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* Irrigation Pocket Book.

DISCUSSION ON
THE POSSIBILITY OF FLOOD REGULATION AND CONSERVATION IN THE HIMALAYAS FOR IRRIGATION OR POWER.

Mr. A. P. Maddocks.

Mr. A. P. Maddocks remarked that Mr. Meares appeared to suggest that his paper was intended as a challenge to the authoritative opinion that the storage of the flood waters of the Himalayan rivers was not an *economic* proposition. He did not, however, discuss the financial aspect of his proposals but devoted his interesting paper to the question as to whether such storage was a practicable *engineering* matter,—a point on which there was probably no great difference of opinion. With regard to the bye-passing of the flood water through a tunnel, this method of dealing with flood water had been in use—of course on a much smaller scale—for the past fifty years at one of the Reservoirs of the Stockton and Middlesborough Water Board in the Tees Valley. There a vertical overflow shaft or waste pit, with a bellmouthed entrance and circular overflow weir, conducted the storm flow into the bye pass tunnel at river bed level which was provided for the discharge of flood water during the construction of the earth embankment, a water cushion being provided at the bottom of the overflow shaft. The bye pass tunnel was thus permanently utilized for two thirds of its length as the overflow channel from the reservoir. If a similar arrangement could be adopted in the case of the works suggested by Mr. Meares there would be no necessity for more than one bye-pass tunnel, and the construction tunnel could be made to suffice. Large vertical outlet and overflow shafts could be taken up from this tunnel to the surface of the ground at any desired outlet and overflow sill levels, the discharge through the tunnel and the bringing into use of such overflows being controlled by a sluice or sluices at a suitable point or points in the tunnel. The horizontal (constructional) entrance to the bye-pass tunnel would, of course, be thrown out of use and blocked up when the embankment was completed; the tunnel below the masonry blocking would not be silted up, but would be available as a permanent outlet and overflow channel. Apart from the construction inlet a circular overflow weir at lowest draw-off level, with a vertical shaft, bellmouthed at the top, communicating with the bye-pass

tunnel (with a water cushion at its base), would probably suffice for all purposes. A second shaft with overflow weir approximately at the level to which it was considered safe for the reservoir to be allowed to fill* at all times of the year could, however, be provided without considerable additional expenditure. Flood water would then partly be absorbed by the storage capacity in the tank between this level and high flood level, and partly discharged down the two shafts.

Mr. Ram Kishore remarked that Mr. Meares had pointed out that in Northern India the great canal systems were already using a very large proportion of the total water that arrived at their headworks in the irrigating season. During certain portions of the irrigating season they used all the water available at their headworks and could use much more if it was available, with great benefit to the country. The author suggested the construction of rock-filled dams in the Himalayas for the storage of the monsoon discharge to be utilized when the ordinary discharge of the rivers was insufficient and pointed out that the difficulties were formidable, but the prize was great. Mr. Meares seemed to consider that the construction of reservoirs in the Himalayas was the only practicable method of increasing the supplies in the canals fed from the Himalayan rivers during periods when the ordinary river supplies were low, but Mr. Ram Kishore did not think that was the case. In a paper on "Reservoir Projects for the Plains" which he presented before the U. P. Centre of the Institution some years ago he suggested the construction of large reservoirs in the plains in waste land or other cheap land, with banks on all four sides. These reservoirs could be built close to or within a few miles from an existing canal and could be filled from the canal during the monsoon, or at other times when there was water to spare, partly by gravitation and partly by pumping, and could supply water to the canals when there was a demand. So far as he could see there were no engineering difficulties in the way of the construction of such reservoirs, but there was the question of cost. So he had assumed a typical reservoir one square mile in area with earthen banks 20 ft. high on all four sides and calculated the cost per acre foot of water supplied from such a reservoir at times when the demand for water was greater than the supply from the rivers. The cost came to Rs. 3.1 per acre foot including all running charges, interest on the Capital cost and depreciation on the pumping plant, etc. Later he was able to obtain a level chart for an actual site on the Lower Ganges Canal,

Mr. Ram Kishore.

and he worked out the cost per acre foot for water from a reservoir at that site which came to Rs. 2.2. All this was done in 1930 and 1931 when the rates for interest and the price of materials and labour were high, and now that all these rates were low, the cost could probably be reduced by 25% to 30%. He did not know what the cost would be for water supplied from reservoirs in the Himalayas as proposed by Mr. Meares, but it might possibly be as high as or higher than that from the reservoirs proposed by him. Moreover the reservoirs proposed by him could be built a few (even one) at a time, as demand arose, and further experience obtained and improvements made. The Capital cost of a reservoir one mile square including machinery and all overhead charges came to Rs. 2,80,000 approximately in 1930. There was also another method of increasing the irrigated area which was being adopted in the U. P. on a large scale, viz., by sinking State Tube Wells. The charge made by the Irrigation Department for water from these tube wells came to about Rs. 8 per acre foot, and these were beneficial to cultivators and also remunerative to Government. The cost of water from the reservoirs suggested by him compared very favourably with the cost of water from tube wells. However, tube wells had the advantage that they did not require much land and tube well irrigation would never produce water-logging. On the other hand, tube wells could only be sunk where there were good water-bearing strata and for economical working it was desirable that the spring level should not be very low. In the case of reservoirs a low spring level was an advantage. Thus there were many places where it would be better to build reservoirs rather than sink tube wells. The construction of both could be undertaken simultaneously at suitable sites.

The Author.

THE AUTHOR, in reply, said that Mr. Maddocks' remarks were interesting and to the point. The author had challenged the authoritative statement that the question of storage in the Himalayas did not deserve further investigation than it had had—amounting to very little. It was generally admitted that very much more water could be used in the irrigation season if it were available; and when the next famine came it was quite certain that there would be an outcry because no provision had been made for this extra supply. The provision of it was mainly an economic problem, but he thought that he was right in saying that the Himalayan area had been neglected mainly on engineering grounds, because the masonry dam had alone been considered as a means of closing a gorge. Earthen and rock-filled dams had hitherto been confined to low

thor. heights and more or less placid waters. The essence of the proposal was the combined bye-pass and flood outlet; and Mr. Maddock suggested the use of a vertical pipe instead of a horizontal tunnel. That method was in use also at Trollhatten, though the vertical shaft was in rock. As to these alternatives, estimates in each specific case could alone show which was the best; but it was established that a pipe must not pass through an earthen dam; it would have to go well below it or at the side. A pipe overflow could probably be so designed as to fulfil the double function of construction and permanent bye pass.

Mr. Ram Kishore's comments were mainly in support of a different proposal altogether, which he had already urged in a paper. He would store water for the same ultimate use, but on a very small scale; and flood regulation in the Himalayas did not come in.

PRACTICAL NOTES IN CONNECTION WITH THE CONSTRUCTION OF A REINFORCED CONCRETE SUBMERSIBLE BRIDGE OVER THE RIVER NERBUDDA NEAR JUBBULPORE

BY

G. F. WALTON, Member

and

S. B. GUPTA.

In 1927 it was finally decided by the Public Works Department of the Government of the Central Provinces to construct a bridge over the river Nerbudda and so form the last link in the chain of communication between Jubbulpore and Nagpur, the seat of the Provincial Government.

In view of the fact that the bridge was to be a large one, the selection of the most suitable and economical site was a matter of importance.

Tilwaraghat, a point some 8 miles from the town was eventually selected.

In order to appreciate the difficulties in connection with the selection of the site and the construction of the bridge, a proper appreciation of the river should first be obtained.

In its upper reaches this river lies in a deep defile flanked by two abrupt ranges of hills. In fact the whole catchment area is almost equally precipitous and some 8 miles below Tilwaraghat site the river passes through the well-known marble rock gorge. Consequently when heavy rains occur in the upper reaches, the water level at Tilwaraghat rises with baffling rapidity, sometimes at the rate of 30 ft. per hour but more generally at the rate of 2 ft. to 3 ft. per hour.

The difference between the highest and lowest flood level is nearly 78 ft., a tremendous depth if it is realized with this rise the maximum velocity is 15 ft. per second, and the width at the bridge site is over a quarter of a mile.

During the dry season this large river shrinks to a small channel 2 or 3 feet deep by about 100 ft. wide.

Another factor which seriously affects the type of bridge is that during high floods many big trees complete with roots and branches are carried down the river. Sometimes the trees are in a vertical position with the branches rising many feet above the water. At times it is a quaint sight not unlike a floating forest. However such floods are unfrequent and even in mild forms come but once or twice a year and continue for 24 to 36 hours on each occasion.

The course of these drifting trees inclines towards the banks so long as the river continues to rise, but during subsidence of the river the course changes towards mid-stream.

Another interesting point is that so long as the river rises, the water is distinctly warm but as soon as it starts to subside the temperature of the river cools down. These particulars should make it clear that the river in flood is an exceptional one with peculiar differences of its own but some are common to most rivers.

To build the bridge near Jubbulpore certainly presented serious problems and this will perhaps be better understood when it is also realized that of the 78 ft. flood to which the river is subject 40 ft. goes over the top of the roadway.

During the big flood in 1926 the steel bridges over the G. I. P. and the B. N. R. across this river were washed away.

The highest flood level is R. L. 1255 but this is exceptional, in fact there is no other known record of such a flood in the district. The ordinary flood level is R. L. 1230 whilst the normal level of the river during the rains is below R. L. 1215. The lowest bed level may be taken as 1175.00 and the reduced level of the soft rock is 1152.00. This 23 ft. between the river bed level and the soft rock consists of a stratum of coarse sand and gravel mixed with large boulders of hard rock. Neither the river bed nor the soft rock surface is anything like level. The soft rock generally falls away in undulating slopes of from 5 : 1 to 1 : 1 towards mid-stream with deep pockets scattered all over. These conditions had a very important bearing on the operation as will be shown later.

According to the above data in case of high level bridges it would be necessary to lift the road level a few feet above high flood or say a reduced level of 1260 ft. which would be 108 ft. above the soft rock level as the intervening layers of sand and gravel might easily have been scoured out by such a turbulent river.

As the usual high flood level is not more than 1230 ft. an enormous additional height and length of bridge would have been required for the sake of the two short floods which happen as a rule once or twice a year.

There was therefore a distinct economic advantage in adopting a submersible type of bridge whereas the disadvantages were trifling.

A road formation level of 1215 ft. was therefore adopted and the bridge was designed so that abnormal floods could pass over it without damage.

As the water in the river had a velocity of 15 ft. per second serious consideration had to be given to the fact that large trees and logs floated down during the flood season. It was necessary that the bridge should give the least possible obstruction to these objects, that is to say when the trees hit the bridge, as they would, they should be allowed to float away as soon as possible and not accumulate a lot of debris. It was therefore important that there should be no under-beams or pockets or ornamental work on the side that would retain floating logs or trees, etc. If a log were held in a pocket or alongside the bridge it might in course of time do a lot of serious damage by hammering on the concrete. The tremendous power of these floods may be appreciated by the fact that the great flood in 1926 not only washed away two steel bridges on this river but when one of the girders was eventually found a long distance down stream, it was discovered that this girder had been pierced by a log and damaged to such an extent that it could not be used again.

The live load for which the new bridge has been designed was considered to be approximately equivalent to 12 units B. S. loading with 50% impact and a temperature variation of plus or minus 20°F.

All these conditions point to the fact that a structure of the strongest material and construction was required, so Reinforced Concrete was chosen. This selection was further supported by the fact that good sand, gravel and boulders were available in large quantities in the river bed. A monolithic structure of Reinforced Concrete with a central span of 200 to 300 ft. would probably have been the most economical, but owing to the comparative cheapness of stone masonry in the locality it was decided to build Reinforced Concrete arches over piers constructed in coursed rubble masonry with plum-concrete hearting.

The plan finally adopted consisted of 14 spans of which 8 spans were each of 50 ft. and the remaining 6 spans 105 ft. each.

The wing walls at one end of the bridge were 125 ft. long and at the other end 40 ft. in length according to Drg. No. 1E, so the overall length of the bridge is 1222 ft.

As this is a first class bridge, the width chosen was 21 ft.

As an additional precaution against any unforeseen pressure which might occur twelve old rails were built up inside each pier from the foundation up to the springing of each arch. The piers were provided with cut water nosing of Basalt stone. Open foundations were adopted even though there was a general feeling of doubt and uncertainty as to their success. They are the safest and best if it is possible to complete them with reasonable economy.

The geological data and the result of borings, supplied to the contractors, gave no indication of the serious difficulties that were eventually encountered in actual operation and moreover could not be expected to show what the true position was, as fissures were encountered in the rock foundation which could not be indicated by any method of boring. In the small spans the soft rock was found at a high level and the bottom of the foundations were practically above dry water level, thus their construction was quite a simple matter, but in the case of the large central spans it was very different so an attempt was first made to build the foundations within a steel sheet pile cofferdam.

In February 1929 a start was made on the small spans, but work could not be seriously commenced till the next season (1930), on the large spans as the bulk of the necessary plant and machinery had to be transported from Calcutta.

Though it arrived before the monsoon, local opinion so strongly persisted in the view that the river would scour out any steel piles left in the bed, that in deference to this local view, pile driving was left over till 1930, as it could not have been completed in the short part of the first season then available. Local opinion was however entirely wrong; even the stone blocks brought into the river bed for masonry work and which had to be left there during the flood were not washed away.

As the working season for this river at Tilwaraghat is very short, only about 3½ months, it became necessary to carry or haul all the plant and machinery from the river several times before the bridge was completed. This re-handling of machinery in addition to the cost of remaking the surface road and temporary bridges each season proved to be relatively expensive as there was a rough bank nearly 70 ft. high which had to be negotiated each time. It should be remembered that a flood sometimes arrives and rises very rapidly with practically no previous warning.

Strangely enough, though the river bed is all covered with gravel and soft rock, no suitable stone was available for the masonry work. All the stone for this work had to be transported at least 8 miles from Katangar Quarry near Jubbulpore. Some of the Basalt for the cut-waters had to be taken 15 miles. The total quantity of stone masonry was about 187,000 cft., the bulk of which was transported by carts which were extremely slow.

Incidentally a particular machine was required urgently from Calcutta so it was sent by Motor Lorry all the way by road from Calcutta to Jubbulpore, nearly 750 miles. The lorry landed safely without any serious hitch in spite of the fact that at one bridge, the machine it was carrying had to be lifted out of the lorry, manhandled over the bridge by coolies and then reloaded into the lorry again on the other side after the lorry had made its perilous journey over the bridge alone.

For the transport of cement—6 miles from Madanmahal Station a 1-ton lorry was eventually used.

In December 1929, that is at the beginning of the second dry or working season, a commencement was made in Pier No. 7 by driving 15 in. by 5 in. sheet piles so as to form a cofferdam. As the sites for the other central piers were still under water they could not be started till much later on.

From information obtained from the geological section, it was calculated that the top of the 20 ft. piles would be above water level after allowing them to penetrate 1 ft. into the soft rock, but contrary to expectation the rock was found to be at a greater depth. Thus the piles had to be driven 3 or 4 ft. below the lowest water level. Consequently they all had to be redriven when the water subsided.

The rush of water into this cofferdam was so great that three 8 in. dia. centrifugal pumps driven by a portable steam engine and two oil engines had to be installed for completing the cofferdam.

After the sheet piles had been completed the area behind them was excavated to a depth of 1 ft. below the top of the piles and the entire sloping area was filled with puddled clay and further protected with clay in gunny bags: Sheet piles were similarly driven in Piers Nos. 4 and 6 as soon as the water level was low enough to permit the work to proceed. The superstructure for the end piers was started as soon as the water level had gone down sufficiently. Thus by the middle of February 1930 both the abutment and wing walls as well as Piers Nos. 1, 2, 10, 11, 12 and 13 were complete up to the springing of the arches. The foundations of the abutment Piers Nos. 3 and 9 had been taken in hand, but the site for the central piers was still under water.

Considerable difficulty was encountered in re-excavating Pier No. 3 which is in close proximity to the stream. It was, however, found possible to reduce the percolation into this cofferdam with the help of timber shoring and puddle bags along the side of the stream. In addition a small cement concrete wall had to be built. Whilst this work in mid-stream was in progress, centring for the end spans was commenced from the abutment ends.

For the first span on the Seoni side the whole span was temporarily filled up solid with earth packed between dry stone walls. All the rest of the centres were of timber work.

In the meantime the excavation and timber work for the cofferdam of No. 7 Pier had been commenced and also the open excavation for Pier No. 8. The top of the rock in No. 8 was only 12 ft. below the river bed and 8 ft. below the water level. When excavation had been taken down to rock it was found that the surface was so rugged and full of pockets that "blowing" started immediately. In some places the water pressure displaced the concrete wall. This necessitated a further protection so the walls had to be filled behind with puddle bags, dismantled and re-built after the pockets had been filled with cement concrete. By this method it was possible to finish the rock cutting up to a depth of 5 ft. below the lowest rock level and to lay the foundation.

In order to carry the water to the pump sump, a drain was formed just outside the foundation. In the sump one 8" and one 6" pump were found to be sufficient to allow the masonry work to proceed.

Pier No. 7—The size of the foundation at the bottom of the central pier was approximately 38′ × 18′. The rock on top was soft and fissured so it was desirable to take the excavation 5′ into the rock in order to avoid the possibility of damage due to the river scouring. The size of the cofferdam was 50′ × 30′. This allowed approximately 6′ all round for drainage and protecting work.

As the excavation in this pier came nearer to the rock and the suction head increased, the water pressure became so great that one 10″, five 8″ and one 6″ pump were not sufficient to keep the water under control.

Owing to the obstruction of boulders at the time of driving, some sheet piles were deflected from the vertical and broke their clutches, thus leaving serious gaps through which water carried large quantities of sand and gravel. In some instances the sheet piles were split for some distance producing somewhat similar results. It was further found on examination that there were pockets and fissures in the rock which ran under the sheet piles like channels and so formed additional passages for the water to pass from the outside to the inside of the cofferdam, as it was quite impossible to drive steel sheet piles into these narrow long grooves. It soon became quite evident that a different type of foundation was necessary and as the conditions of Piers Nos. 5 & 6 were likely to be similar to or worse than those of No. 7, so the work of all three piers was postponed until the P. W. D. decided what type of foundation they were prepared to accept. In the meantime the steel sheet piles had been completed in Pier No. 6 and the cofferdam stood ready for excavation.

When it was evident that no progress was possible during this season on these piers, No. 4 was taken in hand. Here the rock level was considerably higher than No. 7 and narrower piles were used. The cofferdam was also divided into two halves by means of a line of sheet piles across the middle.

Work in the down stream—half was carried out without much difficulty and the masonry in this half was brought up to a level of 5 ft. below the river bed, where it was stopped so that it could be joined on to the other half. Excavation and timbering in the other half was then pushed ahead, but unfortunately a blow was found through one of the piles splitting and through a broken clutch. It was however possible to keep the water under control with three 8″ pumps and at this time the river level was at its lowest.

When the rock cutting was actually finished, but before the concrete could be placed a flood suddenly came down without any warning and so stopped the work. As the water rose 5 ft. in 10 minutes, there was no chance even to remove tools and plant so the upstream half of this foundation had to be postponed till the next season.

During this period work on the end span was progressing well so by the close of the season of 1930, all the five arches (50 ft. each) on the Jubbulpore side and the three arches on the Seoni side were complete. Thus at the end of the season 1930 before the monsoon burst the 50 ft. arches, the two abutment piers and half of pier No. 4 were finished; and pier No. 8 had been built up to springing level. So far as pier No. 7 was concerned there were two possible alternatives under considerations:—1. R. C. Piles. 2. Wells.

There were, however, very serious objections to well foundations, as the same difficulties would occur as in the case of the cofferdam, owing to the existence of gravel and boulder in the soil, the undulating character of the rock, and the presence of pockets in it. Secondly, the same sets of circumstances pointed to the danger of the tilting of the wells. Finally the cost of well sinking in rocks would have been prohibited.

Therefore, R. C. Pile foundations were the only alternative left; but in this case also, several important points had to be thoroughly investigated—first whether it would be possible to drive reinforced concrete piles through gravel and boulders into the soft rock and obtain sufficient penetration to prevent scour. Secondly, whether it would be possible to make the place round the piles sufficiently strong against scour, by cement grouting round the bottom. For various obvious reasons piles cast *in situ* were ruled out. Precast reinforced concrete piles were considered to be the only practical alternative. In order to definitely prove that R. C. Piles were feasible, one was cast and successfully driven with a two ton drop hammer 2 ft. into the soft rock.

The experiment with cement grouting was also carried out, through an 1½″ dia. G. I. Pipe which was provided with an iron shoe and a socket cap at the top, and then driven to the toe of the pile with a 14 lb. hammer. The experiment was made near No. 8 pier, where the rock was 13′—14′ from the bed and 5′—

6′ below the water level at the time. After a few days the place was excavated and the grout removed. It was found to have covered an area of 3 ft. and a depth of 3 ft.

The pile foundations that were eventually accepted were designed to carry a total vertical load of 1,650 tons and the unbalanced horizontal thrust due to live load of 80 tons, and the horizontal thrust on the downstream side due to flood pressure of 90 tons. Thus 32 Nos. 14″ R. C. Piles in four rows of eight each were designed to carry the vertical load. 8 Raking piles, four on each side, were provided to take the unbalanced thrust, at a rake of one in three, and 6 more raking piles were placed on the down stream side to take the horizontal thrust due to flood. In the beginning of the season of 1931, the manufacture of these piles were commenced.

The reinforcements in the piles consisted of four $\frac{3}{4}$″ dia. rods and $\frac{1}{4}$″ helical binders at 3″ pitch with $\frac{3}{8}$″ stiffeners at 3 ft. centres. The size of the core was 11″ × 11″.

The Piles were cast in wooden boxes close to the edge of the water and special care was taken to ensure that they were straight. The proportion of the concrete for the head of the pile was 1 : $1\frac{1}{2}$: 3 and for the rest of the pile a proportion of 1 : 2 : 4 was used. The water cement ratio was 5.25 gallons per cwt. of cement. For the first ten days the piles were matured under wet bags and then rolled over into trenches, where they were kept submerged for at least two months.

Two sets of pile driving plants were erected to expedite the work. One set was used for the vertical piles with the 3 ton drop hammer, and the 2nd. set for batter piles with the two ton drop hammer. As the pile-heads were to be driven to a depth of 10′—12′ below the river bed level, and 8′—10′ below water level, the ground had to be excavated to the bottom of the capping slab with the help of pumps and clay bags, in Piers No. 5 and 7, and inside the sheet pile cofferdam in Pier No. 6. The piles were driven down to refusal. Driving with a dolly was found unsuccessful for such hard driving. The specimen blocks of 1 :2 :4 concrete used in piles were found to develop a strength of 6,000 lbs. sq. inch in 28 days—as reported by the Alipore Test House.

Though it was specified that piles should be considered as driven to refusal when a $2\frac{1}{2}$ ton drop hammer with 8 drops from a height of 4 ft. would not penetrate more than $\frac{1}{4}$″, driving was continued until there was 1′ 6″ to 2′ 0″ penetration into the soft

rock and this was only possible by 12 ft. drops with a 3 ton drop hammer; any further penetration was practically impossible. The piles were then examined by excavating round the upper portion to ascertain if there was any damage caused by such hard driving, but none whatsoever was found. Heavy boulder-filling under and round the capping slabs was then put in, as scour-protection. The heads of the piles were then dismantled and 5 : $2\frac{1}{2}$: 1 cement concrete 1 ft. deep was placed round them. Over this, 2 ft. deep R. C. Concrete slabs 4 : 2 : 1 were laid. The rods of the broken pile-heads were turned down and secured to the re inforcing rods of the capping slabs; the bottom of vertical rails were also embedded in this slab.

There are twelve 75 lbs. rails provided in each pier. Over these capping slabs, piers with C. R. Masonry, and Plum Concrete Hearting, were built up. Thus at the close of the working season of 1931, all the central piers were completed, and 6 Nos. 105′ centred arches still had to be completed. It should be noted that several times during construction of the bridge the arches were subject to floods 15 ft. to 20 ft. above the crown of the arches.

Owing to the late rains the river water level did not subside sufficiently till January 1932 so a start on the staging for the 105 ft. arches was delayed. It was then found possible to erect the staging on sand filling. This staging consists of 8″ sal ballah spaced 6 ft. apart along the bridge and 4′—2″ across, standing on sleepers sufficiently spread to allow 7 sft. bearing on ground, the total load that had to be carried by each ballah was 3.5 tons. These props were braced by 5″ × 2″ and 4″ × 2″ scantlings both horizontally and diagonally both ways and bolted up to make them as rigid as possible. On top of these props 9″ × 3″ longitudinal runners were bolted to the required curvature of the arch. In order to bring the load vertically on the props 10″×5″ timber capping blocks 15″ to 18″ long were used between the bottom of the 9″×3″ runners and top of prop. Wedges of hard wood 12″×3″ were used at the bottom of each prop so as to enable the centring to be released after the concrete had been completed. On the top of the runners 6 in. by 2 in. C. P. teak planks were fixed as lagging. The lagging was fixed 2 inches at the crown above the required level, so as to allow a margin for settlement. On the lagging 1″ dia. reinforcing bars 8″ centred with ¾″ dia. distributors 1′—6″ apart were placed both on the top and at the bottom of the arch ring. Additional ¾″ dia. bars were placed 8″ apart

from the springing to 1/10 span towards the crown to provide additional strength at the haunches of the arch. Out of six 105 ft. arches the first was concreted in the beginning of February 1932.

In order to complete the arches by the middle of May it was necessary to have four sets of staging and centrings. To reduce the width of the stream to its minimum and to finish the concreting of the arches as early as possible; 6 ft. of sand filling had to be done under the staging in some cases and this in places had to be protected by sand bags and timbering.

In order to keep the stream running a diversion was considered to be both expensive and dilatory, the staging over the stream therefore had to be carried on ballah piles with 15′ × 5′ sheet piles as girders.

There was approximately 6,000 cft. of concrete in each arch and on an average it was generally completed in 4 days. Two temporary hinges near the springing and one at the crown were left at the time of concreting. In all reinforced concrete work 1 : 2 : 4 concrete was used and the specimen test blocks gave results up to 6,000 lbs. per sq. in. as reported by the Alipore Test House.

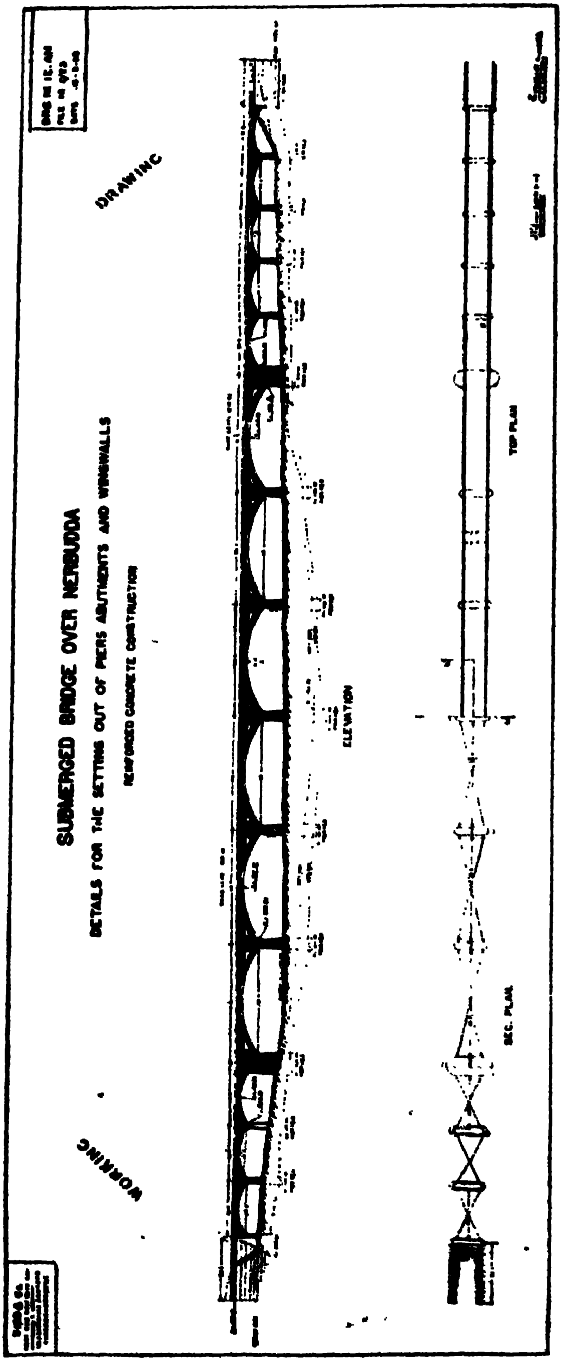
Approximately 1,100 tons cement and 264 tons of Steel rods were used on the bridge. The haunches of the arches were filled in with plum lime concrete hearting and on these 8′×8″×6″ Salya stone sett paving was laid in cement mortar over 3″ lime concrete.

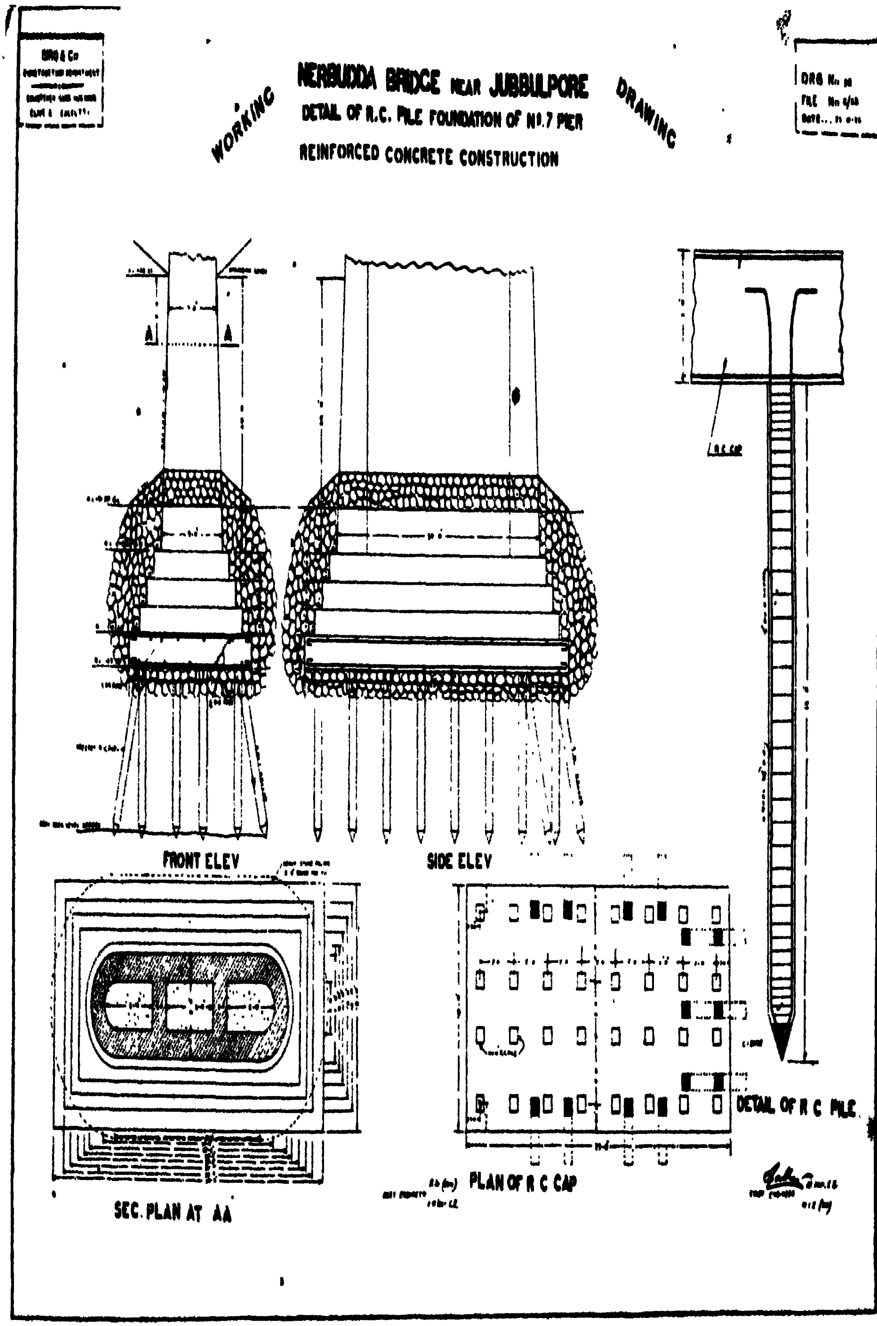
Reinforced concrete coping flush with the paving was constructed with a groove to allow the railings to be accommodated during high floods. The railings are collapsible so that when a high flood threatens to submerge the bridge, they can be lowered and let into the groove of the coping in half an hour's time.

The total cost of the scheme including approaches was approximately 7 lacs.

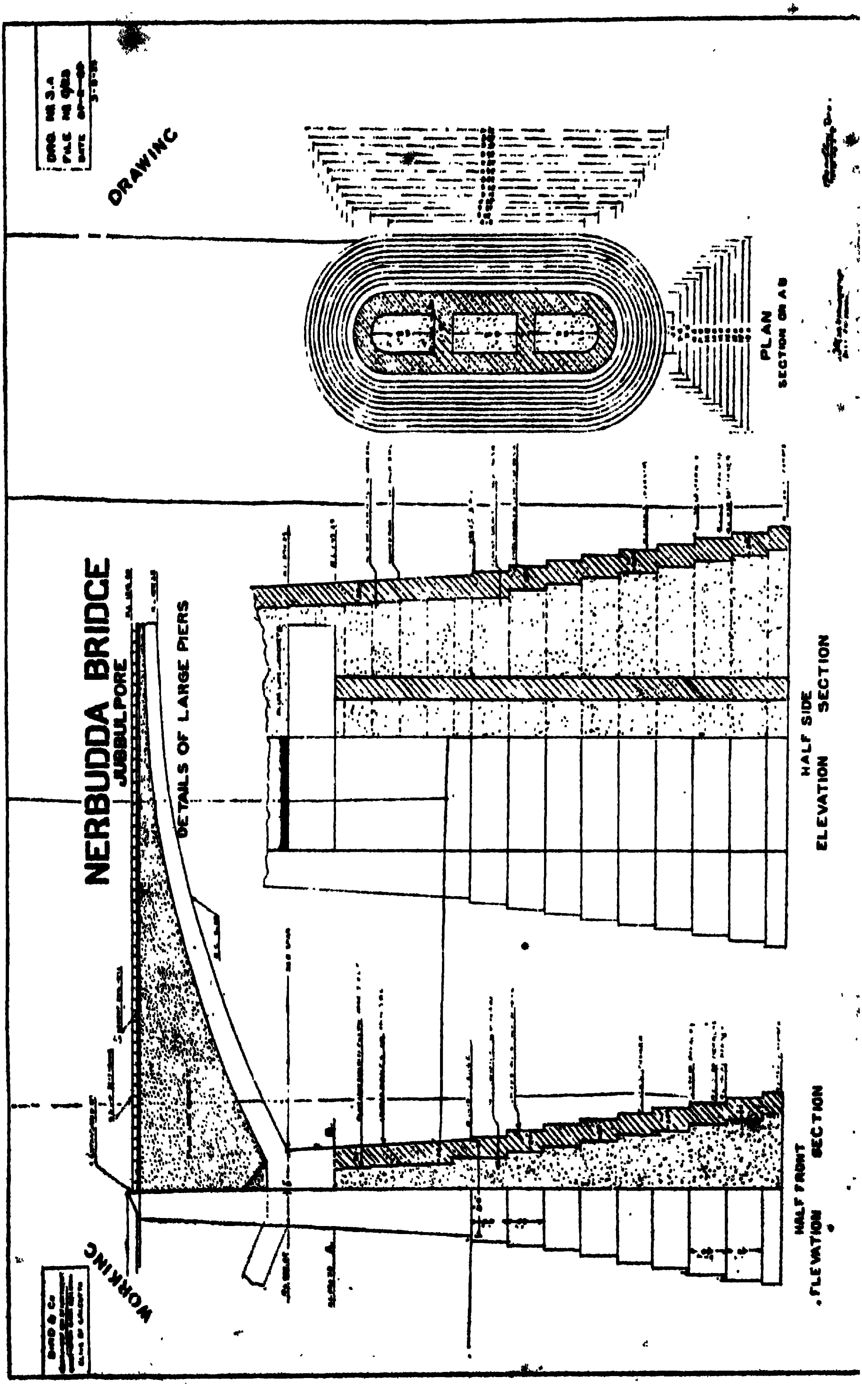
The bridge was designed and constructed by the Construction Department of Messrs. Bird & Co. of Calcutta under the direction of Mr. G. F. Walton, M. Inst. C. E., M. I. E. (India), and Mr. S. B. Gupta was the Firm's Resident Engineer. On behalf of the Public Works Department, Central Provinces, (under whose supervision the work was designed and executed), Mr. J. A. Baker, C.I.E., was Chief Engineer, and Mr. H. A. Hyde, M.C., Superintending Engineer, with Mr. A. W. H. Dean, M.C., A.M.I.C.E., Executive Engineer and Rai Sahib Ram Saran, Assistant Engineer, in direct charge.

WALTON & GUPTA ON THE NERBUDDA BRIDGE.





WALTON & GUPTA ON THE NERBUDDA BRIDGE.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JUBBULPORE
DETAILS OF LARGE PIERS
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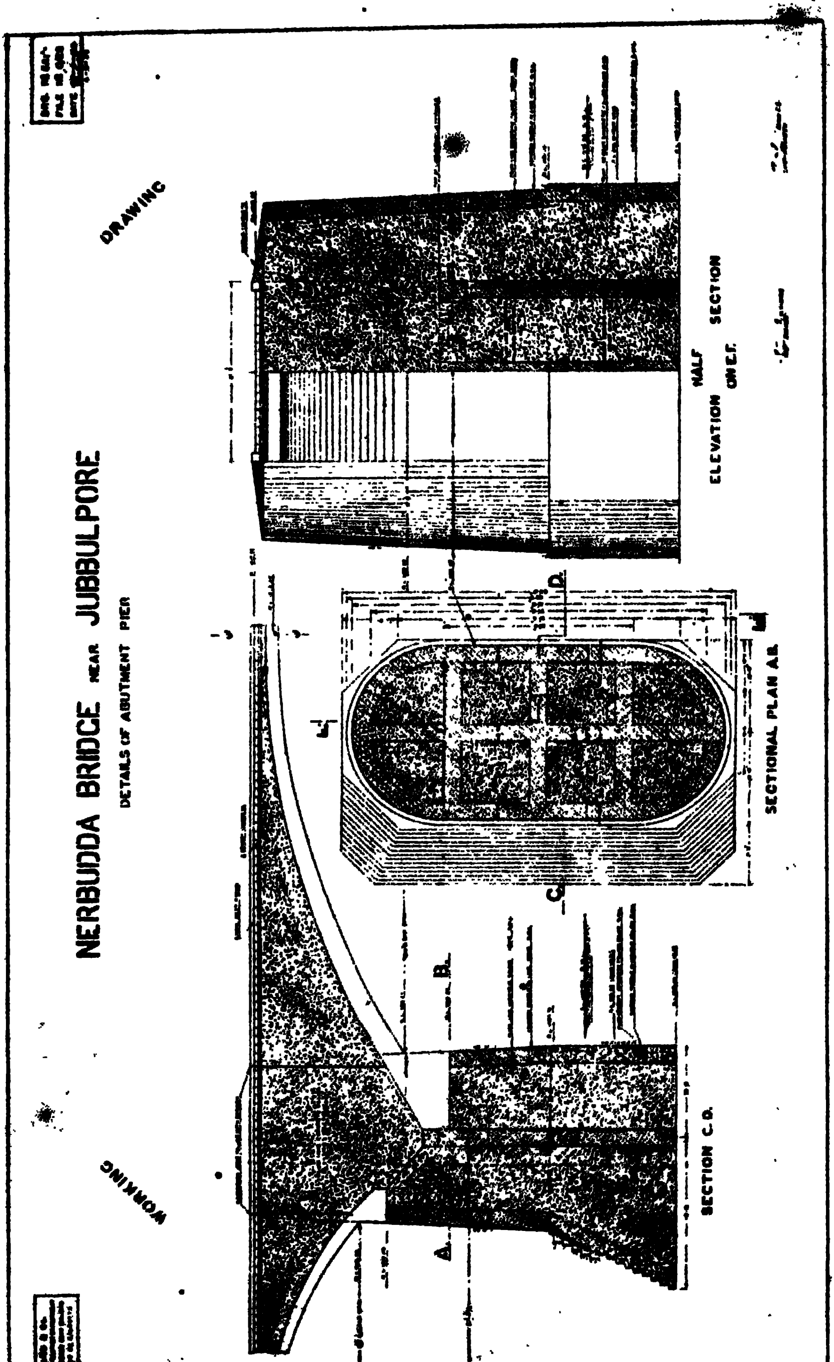
NERBUDDA BRIDGE NEAR JUBBULPORE
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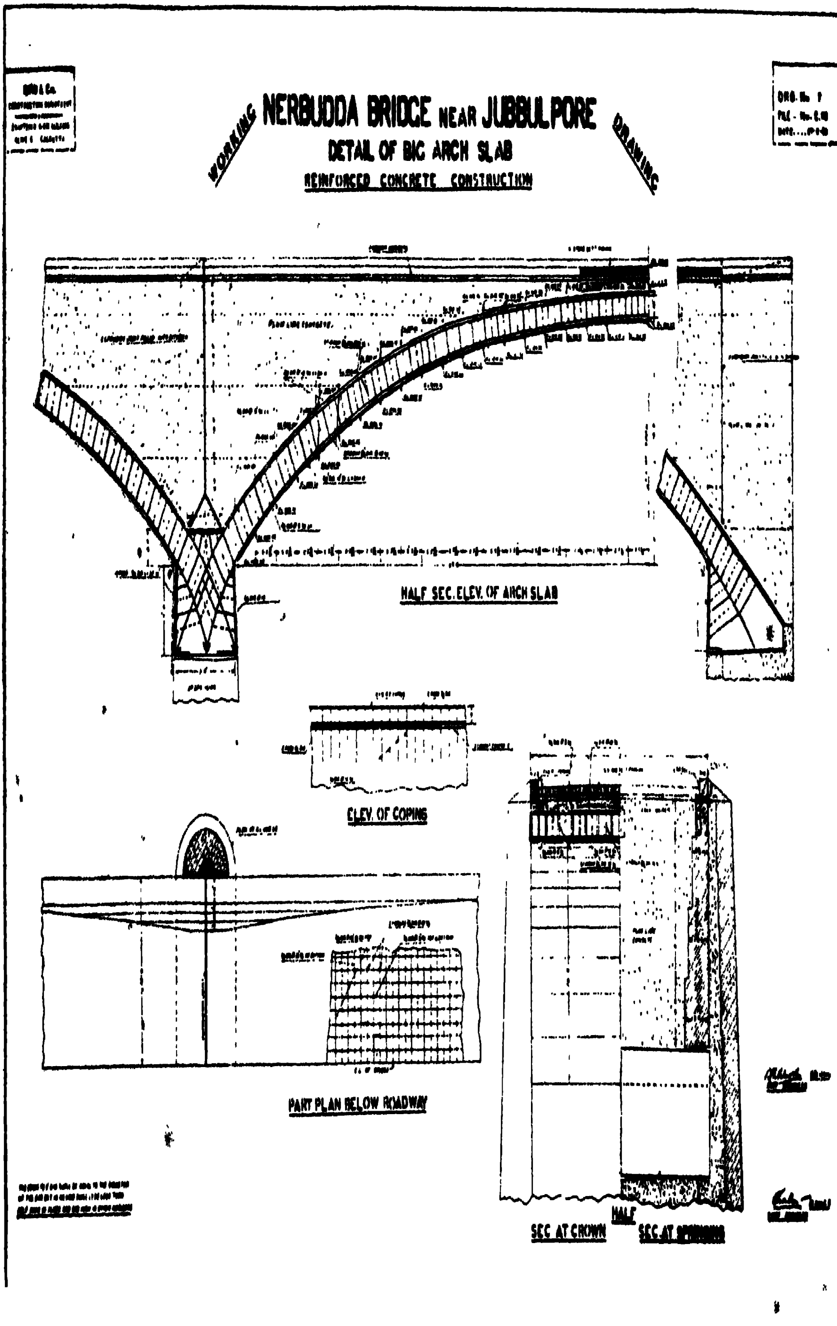
SECTIONAL PLAN A.B.
SECTION C.D.

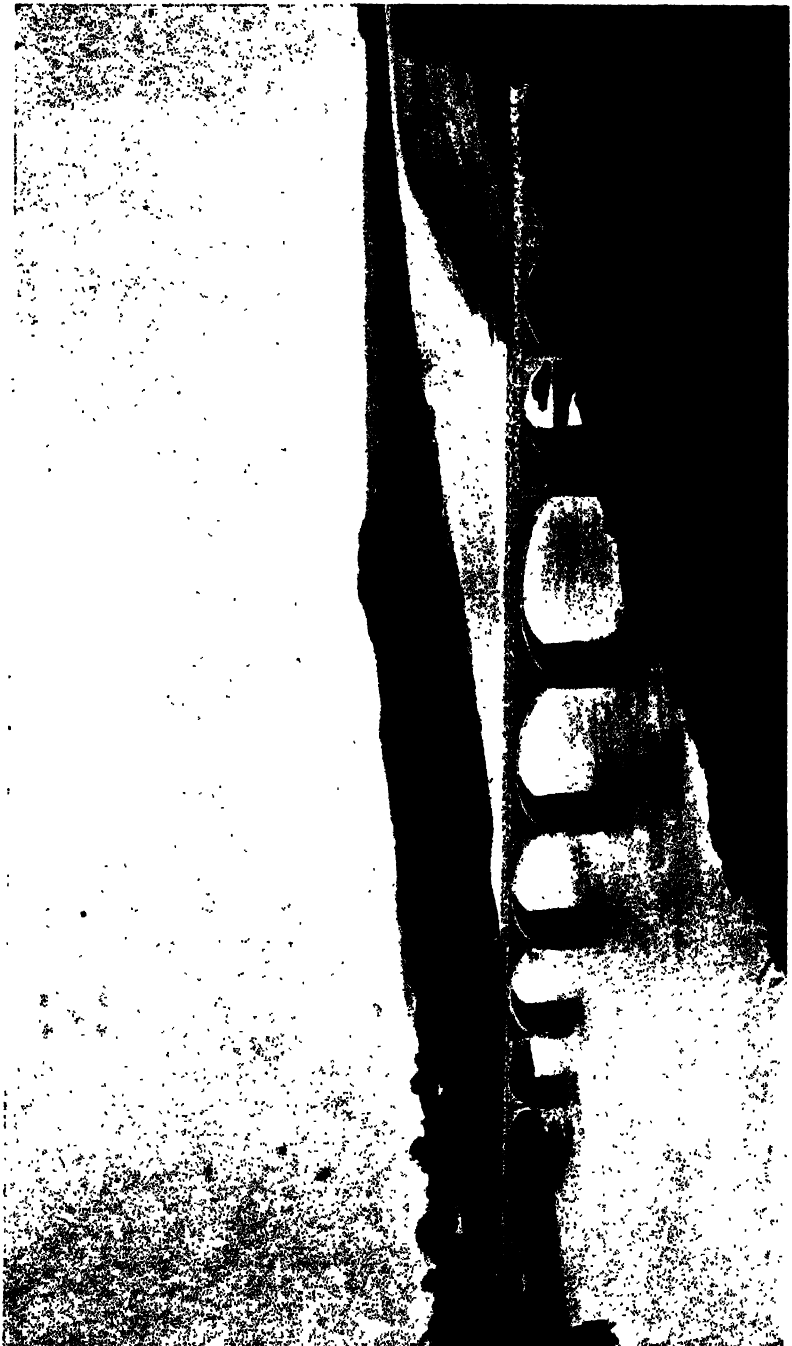


WALTON & GUPTA ON THE NERBUDDA BRIDGE.

Tilwaraghat Bridge, Jubbulpore.

Iwaraghat Bridge

WALTON & GUPTA ON THE NERBUDDA BRIDGE.



Subme ble Bridge he Nerbudda Jubbulpor

DISCUSSION ON

PRACTICAL NOTES IN CONNECTION WITH THE CONSTRUCTION OF A REINFORCED CONCRETE SUBMERSIBLE BRIDGE OVER THE RIVER NERBUDDA NEAR JUBBULPORE.

In opening the discussion on the paper Mr. G. F. Walton pointed out that it had been chiefly written by Mr. Gupta as he was in charge of the work at the bridge site.

In connection with Pier No. 7 a very serious difficulty occurred, as explained in the paper, due to the percolation of water through fissures in the rock. These fissures not only allowed water to percolate but unfortunately the water brought a huge quantity of gravel with it. The gravel, particularly at the bottom of the river bed, was very clean and had very little clay or sand which might have been expected to hold back the water to a certain extent. At one stage the soft rock on Pit No. 7 had been almost wholly exposed, only the low corner where the fissures occurred and where the water and gravel came through in large quantities, remained unexposed. In spite of the fact that extra timber and gunny bags had been placed inside the steel sheet piles and strutted tight on to the steel sheet piles in order to prevent or reduce leakage, a tremendous quantity of water and gravel still came through into the pit. A huge cavity must have been formed behind the cofferdam with the result that the vibration caused by the pumps allowed the sheet piles to fall back towards the cavity and so release the timber. Consequently the whole timber and sheet piles collapsed, but a movement was noticed, so the Engineer was able to get his 22 men out of the bottom of the Pit without injury to anyone at all, in spite of the fact that it only took 2 or 3 minutes from the first indication of movement, before the pier was a jumbled mass of timber, steel piles and pumps. As a result of this it was finally proved that further progress on open foundations would be very expensive and almost impossible unless compressed air was used. An alternative method of reinforced concrete piles was therefore accepted. This particular work had been carefully inspected by all the Engineers concerned a couple of days before the cofferdam gave way, so it could be fairly well acknowledged that reasonable precautions had been taken. The surface of the

ground up to the time the timbers dropped showed no signs of settlement, so the cavity, which must have been forming below, evidently became too great to withstand the vibrations that were created by the pumps and so collapsed. Experience showed that heavy sheet piles had no advantage for such work as this over light sections, and their cost in handling and transport, apart from initial cost, was much greater. Mr. G. F. Walton.

Mr. A. I. Sleigh remarked that the first point that struck him was the decision which was taken to allow the bridge to be submerged under particularly high floods thereby saving unnecessary expense in the cost of construction. Having made that decision the next point was to consider alternative designs and it would appear that the design selected was the one which would cause the least obstruction to flood—a most important point to consider when a bridge was allowed to be submerged. It would be interesting to know what height of flood and its velocity were taken in calculating the greatest stresses, which would be set up in the bridge structure by a flood flowing over the bridge. Mr. A. I. Sleigh.

The paper dealt mostly with the difficulty in founding the piers. In describing these difficulties and the way in which they were overcome lay the chief value in this very interesting paper.

The questions that would be asked after reading the paper were:

(i) Was the "Open Foundations" method the safest and best means to adopt for putting in most of the foundations?

(ii) When this method was found to be impracticable in the case of piers 5, 6 and 7, were pre-cast R. C. piles the most suitable foundation?

Opinions would vary as to (i). Whether that method was the most economical depended on whether pile drivers and pumps of low book value were available or not. It would be noted that, in order to pump out the water from the foundations of No. 7 pier, three 8" dia. centrifugal pumps driven by a portable steam engine and two oil engines had to be installed—this was not sufficient, for on page 203 it was stated that one 10", five 8" and one 6" pumps were unable to keep the water under control.

As to the open foundations method being the safest on such a work as the particular bridge depended entirely on whether work could be done under the supervision of staff who were experts in piling or shoring up an excavation, for in order that the work

might be done in a safe way piling etc. must be used. The contractors had the staff and plant and the method used was apparently the most suitable.

On the question of piling the foundations of piers 5, 6 and 7 opinions would differ. It was not by any way obvious, as the authors stated, that piles cast *in situ* would have been an unsuitable type of foundation. Since the stratum through which the pile had to be driven required very hard driving, it would seem that the steel tube used in the cast *in situ* type of pile foundations would be better able to stand up to the hard driving than a precast R.C. pile. Nor was one convinced by what had been written in the Paper that wells sunk under pneumatic pressure would not have been the best and cheapest type of foundation for piers 5, 6 & 7.

When building a bridge it was not only necessary to consider its initial cost: the cost of maintenance was a most important point and a little extra capital cost might be repaid many times over in the saving of annual maintenance charges. The item which would effect future cost of maintenance was scour. The foundations were on soft rock and, in the case of the piled foundations, the piles were taken about 1½ ft. to 2 ft. into the soft rock and the capping slab on the top of the piles was surrounded by heavy boulder-filling. This might withstand the scour at the bridge itself but the obstruction would be certain to cause scour holes below the bridge. The authorities concerned would be well advised to provide in the very near future a suitable outfall to the bridge.

The authors described how the foundation for pier No. 4 was done in two portions: one half was done in one season and the other half in the next season. Were the two halves bonded together or just butt jointed? If butt jointed, then was any special provision made for capping the two portions over and building the pier on this cap?

The authors described how stone blocks which were to be used in the masonry work were not disturbed by a flood. This incident was not an unusual one. When the present railway bridge across the Jumna River (near Saharanpur) was being built, in 1911, a record winter flood came down and carried away a steam hoist. Nothing was seen of the steam hoist till about a year later when a boatman struck something hard with a pole. This was the hoist which had risen to within 4ft. of low water level. Other Engineers had had similar experience of plant, girders etc., being rolled, in course of time, on to shallow islands.

Mr. W. E. W. Crealock remarked that the authors had stated that local opinion indicated that during floods the sand or shingle in the river bed would be in motion to such an extent that sheet piling driven therein would not stand. They subsequently found however that blocks of stone left lying in the river bed were undisturbed by the monsoon floods, and so felt justified in disregarding local opinion. This question of the apparent stability of the river bed during flood would seem to be one of great interest not only in the case of this particular bridge which had pile foundations driven only 2 feet into soft rock, but also as bearing on riverine conditions in general. It would therefore be a great help if the authors would indicate to what extent the evidence of the undisturbed stones was conclusive. Were they, for example, in a position where a maximum velocity of flood might be expected or were they sheltered, or in slack water? Were the floods to which they were exposed comparable with the greatest floods which might be expected? What was the approximate nature of the material upon which the stones rested? Mr. W. E. W. Crealock.

Mr. D. C. W. Tonkin enquired whether in designing the arch any allowance had been made for the loss in weight due to submergence when the water rose over the bridge. Mr. D. C. W. Tonkin.

Mr. R. C. Harvey spoke about the railings and enquired what type was being used. Mr. R. C. Harvey.

Mr. A. L. Carroll asked whether the type of pile foundation followed for Nerbudda Bridge Piers was similar to the foundation work done on the very similar R.I.F. Submerged Bridge built by the P. W. D., Central Provinces, over the Weinganga River and what the Bridge would have cost if coursed Rubble Masonry Work had been done. There was, he thought, plenty of good stone within tramming distance. Also he liked to have further particulars of the gravel strata passed through by the piles prior to touching soft rock and to know the average sinkage of pile per blow through it. Mr. A. L. Carroll.

Mr. C. Warren-Boulton asked whether Mr. Walton could give any explanation as to why the temperature of the water, as long as the river rose, was distinctly warm, but as soon as it started to subside the temperature of the river cooled down. Mr. C. Warren-Boulton.

Mr. A. T. Weston said that he had listened to the authors' exposition of the problems set them by the necessity of designing this bridge with great interest, but at the risk of being thought simple, he was bound to say that he missed what he might call a statement of the fundamental problem which the authors set out to solve. Designs for bridges were common-place. It was in the respect that this bridge was designed to be of the submerged type during high Mr. A. T. Weston.

flood levels, and therefore designed to withstand the conditions of severe floods in the river that the authors had brought their paper before the Institution. He would therefore have expected some detailed consideration as to what happened when a bridge was washed away, as was the case with the predecessor of this particular bridge. Why was it washed away and wherein lay the weakness of the design of the original bridge? From these considerations the authors would, he imagined, have been able to state the theory of what took place when the previous bridge was washed away, and their proposals for designing the new bridge in such a manner as would prevent a recurrence of the previous disaster. Would the authors therefore please explain what special considerations based on such a study had guided them in their new design? Did they postulate for example, such a possibility as that the river would be in full flood, that all the space between the piers would be filled with the forests of trees and floating debris which they described in their paper to occur, to such an extent that the bridge became equivalent to a dam? Did they calculate the bending moment on the foundational courses which such a condition would involve, and make certain that the line of resultant stress in the piers came within the middle third? He should also like to know, he imagined, precisely how the pressure of the flood water on the bridge was calculated; what allowance was made for dynamic and static pressure respectively.

Rai Sahib K. C. Banerjee remarked that he was sorry that he could not be present to congratulate the authors for the very interesting, complete and instructive paper they had written on the construction of a difficult bridge in the Central Provinces. The paper would be authoritative as several re-inforced concrete arched bridges had been successfully completed by them in Calcutta. The speaker was not a bridge engineer and did not therefore think himself competent to offer any criticism, but being one interested in the subject, he had some questions to ask.

Firstly, he asked how the live load equivalent to 12 units of B. S. loading with 50% impact was decided. A committee on the Re-inforced Concrete Highway Bridges and Culverts in America recommended the following uniform live load for city bridges and bridges on main roads :—

Span in feet.	Under 80 feet.	80—100	100—125	125—150	150—200	Over 200 feet.
Live load in lbs. per sq. foot ...	125	110	100	90	85	80

For second class and other classes of bridges the live load was much less than the above. No impact was allowed in those bridges in American States "as from actual tests made on highway bridges over the state of Iowa, under the joint auspices of the State Highway Commission and the Iowa State College Engineering Experiment Station, it was found that impact due to maximum loads was negligible." The French Government regulations for road bridges required the provision of a superload of 102.5 lbs. per sq. ft. and a footway superload of 82 lbs. per sq. ft., with an impact of 35%. In Germany, as far as his information went, the live load was never more than 112 lbs. per sq. ft. with an impact allowance of 45%. The present Howrah bridge was designed to carry a superload of 28 lbs. per sq. ft. without any allowance for impact. It was also reported that "the average intensity of traffic in Great Britain was heavier than in any other country in the world." It would be interesting and useful to know how this particular loading was adopted and whether it was not possible to reduce it and thereby cheapen the construction of the bridge. Rai Sahib K. C. Banerjee.

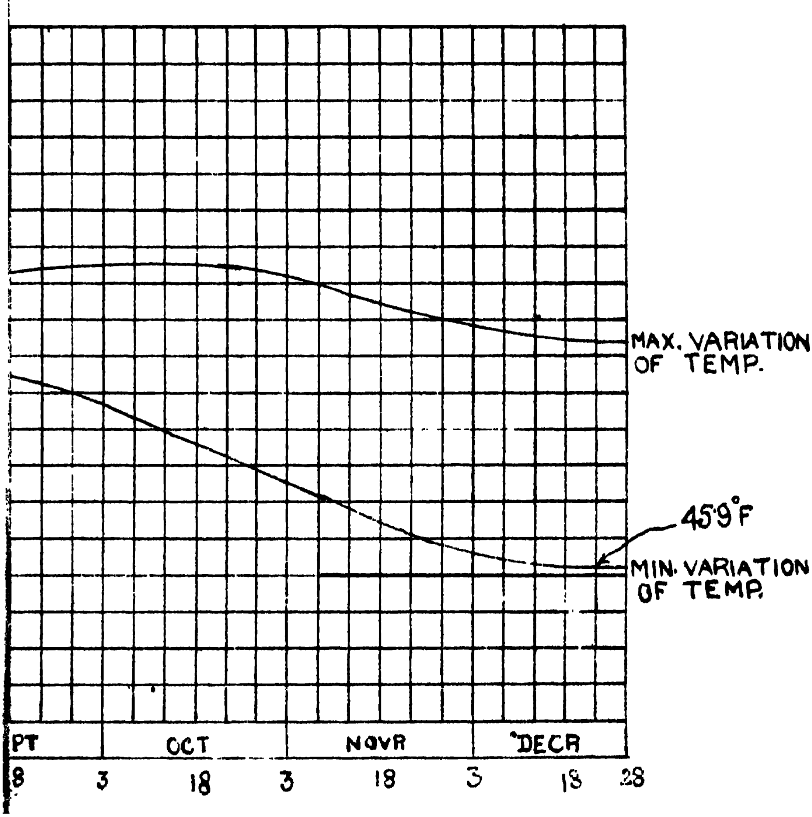
Secondly, he wished to know why a temperature variation of ± 20°F. was allowed in the evaluation of temperature stresses. It was reported by different authorities that in Great Britain such re-inforced concrete bridges were designed to withstand stress due to variation of ± 30°F. In America a wider variation of temperature (at least ± 40°F.) was allowed in re-inforced concrete arches. An experiment was carried out in the Iowa State College of Agriculture for the determination of internal temperature range of variation in concrete arch bridges. According to that experiment, an allowance for 75% of the mean atmospheric variation was recommended. That experiment also conclusively proved that the diurnal variation of temperature had no effect on re-inforced concrete and it took at least 1 to 4 days to develop stress due to temperature variation. Merriman however recommended to evaluate the stresses on the basis of the full variation of temperature. From the attached diagram it would be seen that the normal atmospheric variation at Jubbulpore was 60·4°F. If it was assumed that the temperature of no stress was half of this, then an allowance of ± 30·2°F. should have been made.

Thirdly, in his opinion, every concrete engineer in India would corroborate the fact that concrete of same proportions of aggregate and cement was found to give considerably more strength in India than in other countries. As for instance, the compressive strength of 1:2:4 mixture was usually found to be 3,000 lbs. in 90 days in other places aganist 6,000 lbs. here in 21 days. He

thought that works in India could be made considerably cheaper by taking advantage of this factor. He suggested that the Institution of Engineers (India) should appoint a Committee to investigate the data on which reinforced concrete structures in India should be designed. The economic and climatic conditions, as also the requirements of this country differed considerably from those of other places.

In reply to Mr. Sleigh's questions, Mr. Walton explained that it was considered that a flood just passing over the bridge was the most dangerous as the river carried down with it such a lot of debris in the form of trees, some standing up and some lying flat, etc., thus causing very considerable additional pressure and strain on the bridge and piers. In high floods all the debris could pass clear above the top of the bridge. The velocity of the water was assumed to be about 15 ft. per second. In actual practice, the maximum surface velocity was found to be 8 ft. per second. It was generally admitted that open foundations were the best if they could be economically constructed, but when it became necessary to excavate to excessive depth and particularly when the surrounding material was gravel through which water would pass very freely, and further when the sub-strata were fissured rock, then some other method of obtainung foundations had to be considered. The depth originally proposed for the three main piers proved to be far too great for open foundations. To sink caissons would perhaps have been an ideal method but the cost would have been prohibitive. The total cost of the bridge was absurdly cheap which might be realised if a comparison was made with other bridges in India. Any comparison with English bridges was almost out of the question as the cost of such bridges in England would be 5 or 10 times as great. It was difficult to see what alternative to piles could have been suggested for the money that was available. Because of the fissured rock, wells would have been almost impossible and again more expensive. Piles were the cheapest of the three methods above mentioned. It was not only a question of the capital cost of pumps, but there was the very serious running cost even for pier No. 7, and piers Nos. 6 and 5 were about 7 ft. deeper. It was certainly essential to have expert staff for timbering deep foundations. As already mentioned in the subsidiary notes, the cofferdam of pier No. 7 gave way, in all probability due to the cavity that formed behind the steel cofferdam which allowed the steel cofferdam to spread outwards at the bottom so that the timber struts fell, even though they were vertically strutted, thus allowing the whole cofferdam to collapse. Steel tubes for casting *in situ* piles

SAHIB K. C. BANERJEE—DISCUSSION ON THE NERBUDDA BRIDGE.



river would have been objectionable. In designing the bridge

though they were vertically strutted, thus allowing the whole cofferdam to collapse. Steel tubes for casting *in situ* piles

could have been driven through the gravel, but the gravel might have fallen into the pile tube as they were withdrawn before the concrete could have taken up its position. Furthermore it was almost certain that as battered piles were necessary the steel would have rested on the lower surface of the pile and so corrosion would have taken place. Wells sunk under pneumatic pressure, as mentioned by Mr. Sleigh, might have been a better solution, but the cost would have been tremendously greater, so in consideration of this, they were entirely ruled out as the money was not available. Pier No. 4 was butt jointed. After the steel sheet piles had been extracted, in Pier No. 4 a concrete slab 1′ 6″ thick reinforced with 75 lb. rails, was built upon the masonry work in order to join the two portions together. On top of this in addition a stone slab 1′ 6″ thick was built. The Author.

In connection with scour referred to by Mr. Crealock as well as by Mr. Sleigh, it was not expected that scour would reach as far as the toe of the piles, though in mathematically calculating the strength of the piers it was assumed that this might happen. It would have been possible to place grout at the toe of the piles on the top of the soft rock by means of tubes built into the bridge piers. This was actually discussed but eventually not considered to be necessary. In the authors' opinion it would have been wiser to have kept tubes so that this might have been done and thus make the piers more permanent. Local Engineer's opinion at the time the work was started was that scour might be very heavy and that it would be risky to leave even a steel sheet pile cofferdam in the river during the flood season. The scour in exceptional seasons when the flood rose to its maximum height of 40 ft. might be great, but the experience obtained during the construction of the bridge when the flood never reached a greater height than 20 ft. above the road level, indicated that practically no scour took place. Even cut, dressed masonry blocks deposited in many places remained in the river bed after a flood.* Practically no damage was done to a temporary Bally pile construction bridge through flood, and the steel cofferdams remained in perfect condition.

In connection with the arch design as mentioned by Mr. Tonkin, no special precautions were taken beyond those generally adopted for all good reinforced concrete work, except that all corners, protrusions, hollows, pockets were omitted. For instance a beam and slab design would have been impossible as logs might have got under the slab and in between the beams and caused damage. In a similar way overhanging corbels or parapets which would shelter and prevent the free flow of debris down the river would have been objectionable. In designing the bridge

The Author. allowance was made for loss of weight in the masonry due to submergence.

This brought up the question of railings referred to by Mr. Harvey. They were all of the collapsible type designed especially so as to avoid obstructions and to allow debris to pass down the river during flood. These railings fitted into grooves and could in the small time of 20 minutes all be dropped into their respective slots by a gang of 4 men.

The system of piles at the Bandala Bridge, as mentioned by Mr. Carroll, was entirely different from that adopted on the Tilwaraghat Bridge. For the Tilwaraghat Bridge the piles were mathematically calculated, both as to vertical and battered piles, to withstand the stresses due to either water velocity, dead load, live load or eccentricity of live load. For the Bandala Bridge a type of reinforced concrete wells or even concrete cylinders were sunk. Owing to the irregularity of the ground these cylinders could not be taken down as far as was expected. Consequently vertical piles were driven into the bottom of the river through the centre of the cylinders as an extra precaution.

The bridge was 1,222 ft. long and 21 ft. wide, and it cost Rs. 4,61,000. Detailed cost of a bridge of this description for comparison with that of other bridges was a long subject, but roughly the 100 ft. submersible arches cost a little more than a similar concrete bridge of a non submersible type; approximately the difference was less than Rs. 2 per sft. for the superstructure. For the 50 ft. arches there was practically no difference between the cost of a submersible bridge and an ordinary beam and slab reinforced concrete high level bridge.

A submersible bridge for Tilwaraghat gained tremendously over any other type as the piers would have had to be more than 40 ft. high, which meant at least double the height and double the length of the bridge. The Nerbudda River at Tilwaraghat was subject to exceptional flood conditions. As the foundations of the three central piers were very difficult and expensive it would have been interesting to have been able to consider an alternative scheme with larger spans and so reduce the number of deep foundations. This was not done as the present spans were the maximum so far built for a submersible reinforced concrete bridge. For a non-submersible type the authors felt confident that a 300 ft. to 400 ft. single span reinforced concrete bridge in the centre would have been the most economical.

The gravel varied in size from ½ inch to 3 inches with a few large boulders. It took roughly a day to drive a

The Author.

17 ft. pile 12 feet—partly due to the necessity of keeping each pile in its correct position. The penetration per blow all the way was very small. The 2 ton hammer was at first dropped 4 feet and eventually the drop had to be increased to 8 ft. to get the pile down at all.

In reply to Mr. Warren-Boulton's query Mr. Walton said that the reason for the variation of temperature was unknown to him.

In connection with Mr. Weston's remarks, Mr. Walton said that the paper was intended to deal with the practical construction rather than the design, as the latter would have involved a tremendous amount of extra detail and made the paper too large. He had no details of a reinforced concrete submersible bridge being washed away, but as in the case of Nerbudda Steel Rly. Bridge when a river rose higher than it had been expected to, the velocity of water acting on the girder caused a turning moment on the pier bases, and if the flood could not float the girder off the whole bridge might be destroyed. This bridge was the first for the road, previously there had only been a ferry. These submersible bridges were designed to resist the velocity of the water and allowance was made for trees floating down and impinging on them, but the arch elevation was so plain and simple that little debris could stay at the bridge. There was no chance of a dam being created. On the piers of this bridge the resultant line of thrust was very much within the middle third. The haunches and weight of an arch were very great when compared with a girder, so the bridge was safe for a very much greater velocity than 15 feet per second.

In reply to Rai Sahib K. C. Banerjee, Mr. Walton pointed out that the Road Board had more or less accepted 12 units British Standard loading including impact to be the Standard for main road bridges in India. He was unaware of the reason how the temperature variation was settled. He would point out that experience showed that conditions were generally cooler in a river near a large area of water. This might justify lower variations than for buildings or small bridges in a town. He agreed that conditions in India made it possible to obtain higher strength of concrete at 28 days than in cold climates.